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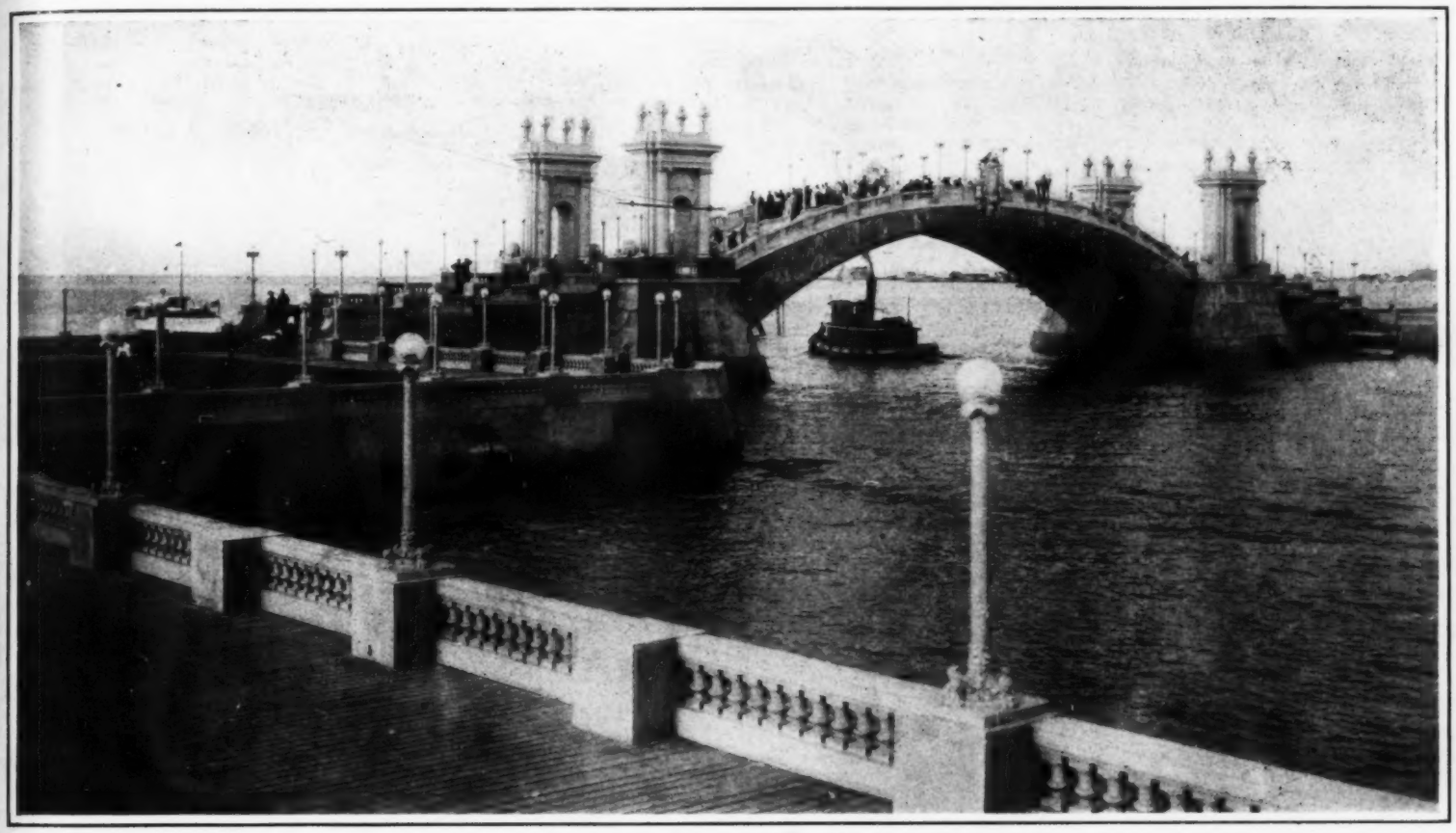
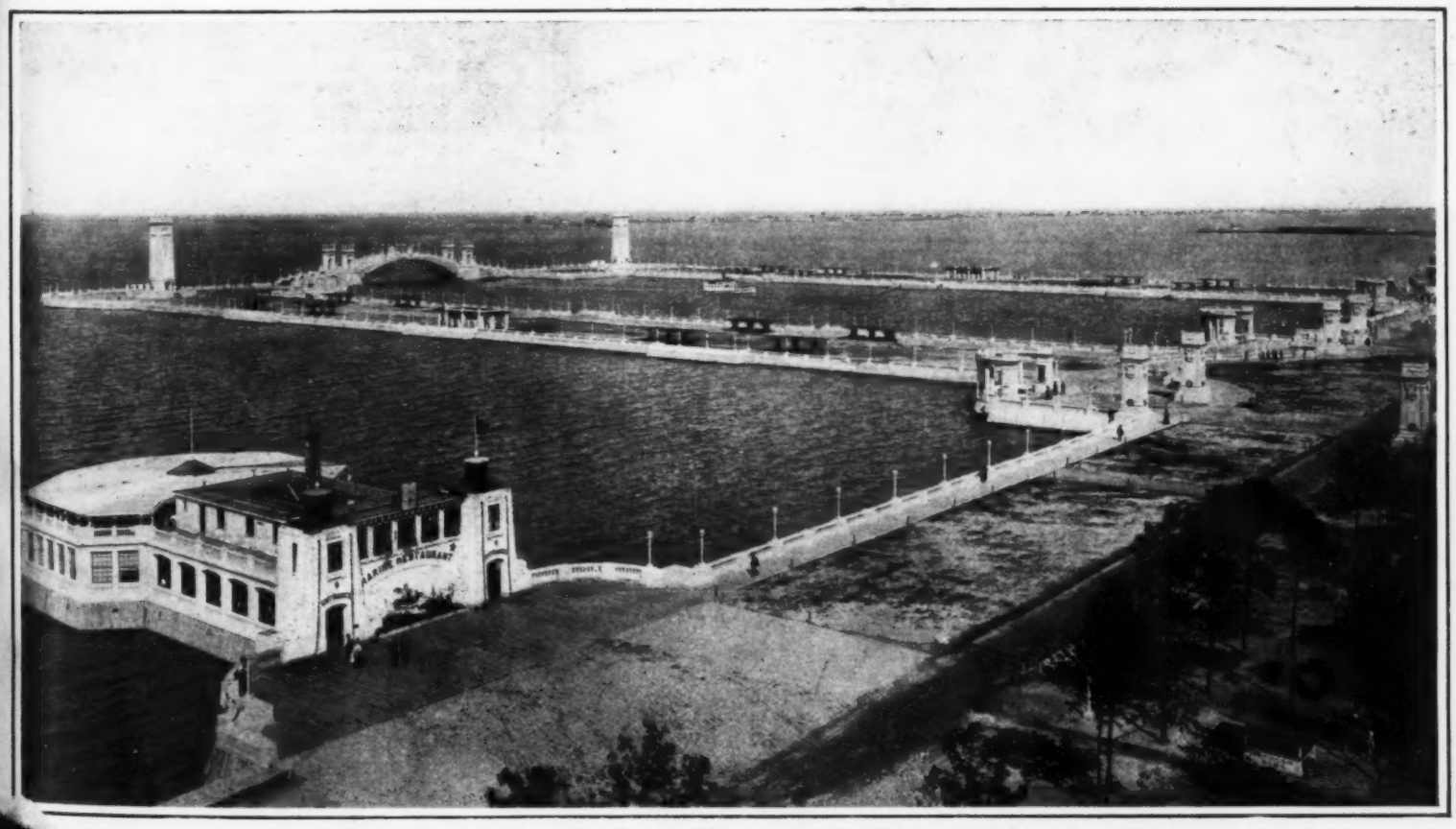


THE GREAT ARCH AT THE END OF THE GOVERNMENT PIER.

The arch has a span of 151 feet 5 inches. It is the largest completed concrete arch in the country.



GENERAL VIEW OF THE PIER, SHOWING THE LINES OF STATELY PYLONS, PERGOLAS, AND LANDINGS.

The pier is 1,200 feet long and 847 feet wide. The basin between the two arms is 1,163 feet long and 547 feet in width. The columns on either side are 80 feet in height.

## THE GREAT GOVERNMENT PIER AT THE JAMESTOWN EXPOSITION.

# THE GREAT GOVERNMENT PIER AT THE JAMESTOWN EXPOSITION.

BY E. DABNEY TUNIS.

PERHAPS there are few people who realize that the great government pier at Jamestown represents one of the most successful and gigantic tasks of modern times.

The plans for this pier were drawn by the Exposition Board of Design, with Robert S. Peabody, of Boston, a veteran in exposition work, as consulting architect, and on the appropriation of $400,000 the contract was awarded to the Schofield Company of Philadelphia October 21, 1906. Ten months later it was a finished structure, work which under ordinary circumstances would have required two years having been accomplished in less than half that time.

The double pier incloses a water basin of 1,280,000 square feet. The plans called for 13,000 piles or more—sheet and round piles both; over one mile of sea wall; about 300,000 yards of fill and about as much as 450,000 yards of dredging. Over 3,500,000 feet of lumber was necessary to complete it.

Fourteen different pile-driving machines were used, as many as three going at the same time. Nine dredges, seven tugs, and twelve scows, all manned with two, and often three, crews, worked from sixteen to twenty-four hours a day on the dredging.

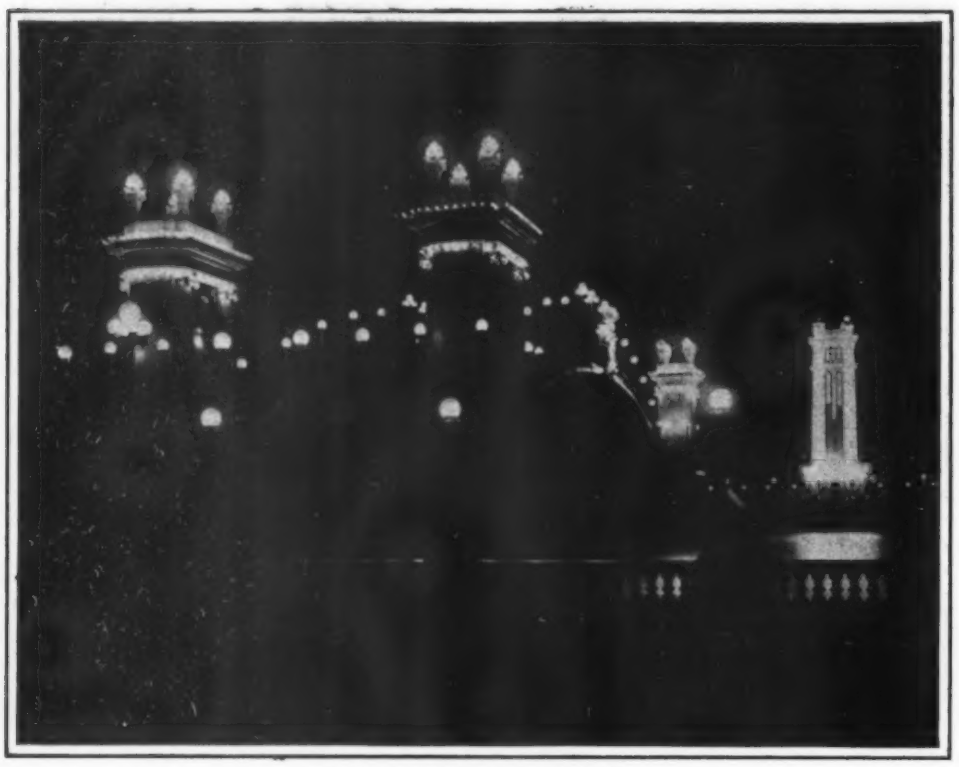
In operating and handling the material for the enormous undertaking, three locomotives, two narrow and one standard gage, were used, while more than two and a half miles of track was laid connecting the various parts of the work. In handling the concrete, two separate and distinct plants were built—one on shore for the four sea walls and end, while that for the arch was built on a temporary trestle erected alongside.

The greatest obstacle met with was the dredging; for the bottom, instead of being sandy as shown in the drawings, proved to be a difficult combination of clay, sand, and sandstone with quantities of stone and small bowlders which defied the best efforts of any but the largest dredges.

The most exceptional and remarkable feature, however, of the whole structure is the one 150-foot reinforced arch connecting the two arms of the pier at the outer end, and gracefully spanning the basin entrance. This arch, placed on a mud bottom and relying absolutely on the bearing powers of the piles driven for its abutments, proved a marvelous feat of engineering, as it is the longest single-span bridge of its kind in the country, and certainly the greatest concrete arch in the world, measuring as it does 151 feet 5 inches from spring line to spring line. In order to place it, over 200 piles were driven in each abutment, the concrete being placed 9 feet below water in two large cofferdams.

Architecturally, the pier presents first two lines of stately pylons, each extending 1,000 feet along the boulevard and terminating in the two arms of 1,200 feet in length, the arms being adorned with pergolas and landing places. Outlining all is the 4-foot balustrade of colonial design, while at each of the four corners giant columns stand sentinel; brilliantly, vividly white by day and towers of flame by night.

Jutting 1,200 feet out into historic Hampton Roads, beautiful, symmetrical, dignified, and grand, this pier stands proudly the superb monument of a loyal country for those who hewed the first stone three hundred years ago.



THE ARCH OF THE PIER AT NIGHT.

## QUALITIES AND METHODS OF USING CEMENT.*

By S. B. NEWBERRY.

THERE are really three different kinds of hydraulic cement in use: Puzzolan or slag cement, natural cement, Portland cement.

A few words on the differences between these may be of interest. The Romans made very good cement, and many of their concrete structures have lasted till the present day. Their cement was simply a mixture of a volcanic scoria, called "pozzuolana," with slaked lime. This, and some other materials such as some kinds of blast furnace slag, have the property of making lime hydraulic; that is, causing it to harden under water Slag cements, consisting of slag ground with slaked lime, are made to-day by the iron companies in considerable amount. They make good mortar, and are useful in concrete kept constantly wet, but are much inferior to Portland cement in strength and hardness.

In 1756, when the Eddystone lighthouse, off the coast of England, was built, Smeaton, the engineer in charge, made experiments to find the best of lime to mix with Roman pozzuolana for use in the work. He found that certain limes hardened better under water than others, and on dissolving in acid found these limes left a considerable residue of insoluble clay.

This was the first discovery that the combination of clay and lime gives hydraulic properties. Smeaton wrote: "I do not doubt to be able to produce a cement equal to the best Portland stone." From this remark the name "Portland cement" is derived.

Soon after Smeaton's experiments, limestones containing a high proportion of clay were found in France and England, and the manufacture of "Roman cement" was begun. It was found that if the stone contained perhaps 25 per cent or more of clay, and was burned at low heat, the burned lumps would not slake with water, but if ground to powder a quick-setting, natural cement resulted, which hardened very well, and this product soon became extensively used. In this country the manufacture of natural cement has become an important industry, though it has diminished with the growth of Portland cement manufacture.

If this natural cement rock is burned at a high or white heat, it melts to a slag which has no cement properties. If, however, we take a limestone containing less clay, generally about 20 per cent, and burn at white heat and grind the clinker to powder, we obtain a slow-setting cement of much greater hardness than the natural product. This is Portland cement. If we could find beds of limestone containing just the right percentage of clay, and perfectly uniform in composition, we could then make Portland cement simply by burning and grinding. But as a variation of ½ per cent in the amount of clay, either way, is enough to injure or ruin the quality of the product, it will readily be understood why suitable deposits have practically never been found.

On the other hand, it is possible to mix carbonate of lime (limestone, marl or chalk) with just the right amount of clay, and thus prepare an artificial mixture which will stand burning at white heat and yield Portland cement of the highest grade. This was first done by Aspdin, in England, in 1827, and the industry rapidly extended in England and Germany. Portland cement was first made in this country about 1878. In 1892, the amount of Portland cement made in the United States was less than half a million barrels; this year it will be over fifty million barrels.

The materials for Portland cement are carbonate of lime and clay. The carbonate of lime may be chalk, as it is in England, or limestone, or limestone containing clay which we call cement rock, rock, or marl.

In some sections of this country, particularly in Indiana and Michigan, fresh water marl deposits are found, in the form of white paste. This is an exceedingly good cement material. Where cement rock or limestone is used, the materials are ground dry. Kilns are getting bigger and bigger each year; some of the factories in the East have kilns 140 and 150 feet long. A rotary kiln is a cylinder of steel lined with fire brick. It is slightly inclined and revolves at the rate of one revolution per minute. At the lower end coal in powdered form is blown in and burns just like a gas flame. The raw material is put into the upper end of the kiln and slowly comes down, gets red hot, gives off carbonic acid, the lime and clay become combined, and finally become white hot when the carbonic acid is all given off and passes out in white-hot pieces about the size of small gravel. This clinker from the rotary kiln consists of black, rounded grains. It merely has to be ground to powder—with addition of 1 to 2 per cent gypsum to prevent quick setting—to produce finished Portland cement.

Progress in concrete block construction is slow, because there are difficulties and prejudices to be overcome, but if one-half the buildings that are now made of wood were to be replaced by Portland cement, it would take a quantity of cement equal to all that is made to-day. Wood is disappearing and is not a good material for building. A good concrete block house costs no more than frame.

The constituents of Portland cement are four: lime, from limestone or marl, and silica, iron oxide and alumina, from the clay. With these four materials we can make Portland cement by combining the right proportions and burning and grinding. But some interesting things have been found as to leaving out one of these constituents. If we leave out the iron and have only silica, alumina and lime, we get a snow-white Portland cement. Or we can leave out the alumina and use only iron oxide; and Krupp of the steel works at Essen, Germany, and Dr. Michaelis, of Berlin, have patented in Europe and the United States a cement which contains no alumina, and in which the alumina is replaced by iron oxide. It resists the action of sea water. This injurious action of the sea water does not make any difference to us in Ohio, and the corrosion by sea water does not alarm us to any great extent. But on the sea coast that corrosion of sea water is a serious problem. It is caused by the action of the sulphates that the sea water contains on the alumina, and Portland cement free from alumina and containing iron oxide in place of it is absolutely unaffected by sea water.

I do not want to leave this subject without saying a little more about concrete blocks and the way they should be made. The secret of making a good concrete block, and something which it seems almost impossible to get people to realize, is to get the material wet enough so that the material will be plastic. All block-makers seem to have the notion that to make blocks dry and sprinkle them with water afterward will produce good results. This is an error, for the use of the water is in causing the mass to settle together into a dense, solid form. Blocks made too dry will always be soft and crumbling, and no amount of subsequent sprinkling will help matters. As much water must be used as possible without causing the blocks to stick to the molds or sag out of shape.

* Abstracted from a paper read before the Ohio Builders' Association.

# THE DEVELOPMENT OF ARMORED WAR VESSELS.—XI.

## ARMOR PLATING IN THE UNITED STATES.

BY J. H. MORRISON.

Continued from Supplement No. 1661, page 278.

IRONCLADS OF THE SOUTHERN CONFEDERACY.

It was not all in the northern and western States that this industry of armor plating was taking such a busy turn. The reason of this sudden activity was the cause of the increased demand over the whole United States.

The first official recognition of ironclad war vessels in the late Confederate States is found in a resolution referred to the Naval Committee of the Confederate Congress on February 27, 1861, on "the propriety of constructing several iron-plated frigates." This was prior to the appointment of the heads of the various departments of the provisional government.

The first mention of an ironclad war vessel by the Confederate States Navy Department is found in a communication by the Secretary of the Confederate States Navy Department to the chairman of the Committee on Naval Affairs of the Confederate Congress under date of May 8, 1861, which shows his knowledge of the subject at the time, and in which he says in part: "The resistance of iron plates fixed upon an unyielding surface to the direct action of heavy ordnance was first fairly tested by Mr. Stevens of New York in 1845, and the result of his experiments proved that wrought-iron plates one inch thick thus supported could not be penetrated or injured by shells, and that the same iron six inches thick resisted all shot, and at every distance." He then recites very much in detail all that had been done in England and France in the development of ironclad war vessels up to that time. He then continues by saying: "These facts are presented for your consideration. I regard the possession of an iron-armored ship as a matter of the first necessity. Such a vessel at this time could traverse the entire coast of the United States, prevent all blockades, and encounter with fair prospect of success their entire navy. Should the committee deem it expedient to begin at once the construction of such a ship, not a moment should be lost."

Referring to Stephen R. Mallory as Secretary of the Navy of the Confederate States, it cannot be said that he inherited any love for marine affairs from his immediate family. When he started out in life he entered politics while residing at Key West, and when Florida was made a State of the Union in 1845 he was appointed custom house inspector, and subsequently collector of customs at Key West. In 1851 he was elected U. S. Senator from Florida; and what is somewhat remarkable for a new member of the U. S. Senate, he was placed as third on the roll of the Naval Committee of the Senate; that would show a strong "political pull." He was moved up on the roll of the Naval Committee until in 1855 we find him chairman of that important committee of the upper house, where he remained until 1861, when he left the Senate. That he had some qualifications for the place on the Naval Committee is found by his speeches at the time the appropriation for the completion of the Stevens battery was before the Senate. He showed a more intimate knowledge of the experiments made by Robert L. Stevens for the building of the battery than any other member of the Senate speaking on the subject at the time. At the same time he was a factor in the legislation that made our early steamboat laws what they were. It cannot be said he was favorably disposed toward the development of the American merchant marine through a subsidy—that he was opposed to. He was a power in the Senate on naval affairs for five years before the civil war, and it is not strange that Jefferson Davis selected him as his Secretary of the Navy of the Confederate States. What was of the most value to him in his new situation was his intimate knowledge of the Stevens battery in its early stages, and the knowledge thus obtained was made of use and value in the rebuilding of the "Merrimac," and the designing of the ironclad gunboats for the Southern Confederacy. There is no doubt that he selected those naval officers, who had recently resigned their commissions in the United States navy, who were the most capable to fill the places as chiefs of the bureaus of the Confederate Navy Department, and to them must be given as much credit, if not more, for their professional skill and knowledge during the experimental stage of the development of ironclad vessels for the Confederate navy, and who had very trying conditions surrounding them. They were mainly young and progressive officers of the Confederate navy, and were well advised of all improvements that were making in naval affairs at that period.

The Confederate States government intended to have an ironclad war vessel built for sea service, as the reference to the blockade clearly shows in the Secretary of the Navy's report referred to. An appropriation having been made by the Confederate Congress, an agent of the Confederacy was sent to Europe to purchase or have built one or more ironclad war vessels in England or France; but he finding it impracticable at the time to accomplish his object, the Navy Department in June or July, 1861, decided to commence the construction of naval vessels in the Southern States. This is no doubt what decided the disposition of the burned hull of the "Merrimac."

The number of iron-rolling mills in the Southern States in 1861 that could roll heavy plate iron, without a large rebuilding of their plant, was not more than five. They included the Tredegar Rolling Mill, the Armory Rolling Mill, both of Richmond, Va.; the Tennessee Rolling Mill near Eddyville, Ky.; the Cumberland Rolling Mill near Dover, Tenn.; and the Gate City Rolling Mill at Atlanta, Ga. The Tennessee mill was the largest of the five mills as a plate-iron mill, having produced prior to this date over 3,000 tons of sheet and plate iron in one year. The Atlanta mill was then but two years old, having been established for the purpose of rolling iron rails for the southern railroads, and had a capacity for producing 12,000 tons annually. The Tredegar Iron Works was the oldest of all these mills, having rolled the plate iron when they constructed the iron-hull revenue cutter "Polk" in 1846. The facilities for doing any heavy iron work at the Tredegar Iron Works at the opening of the civil strife must have been very limited for a plant of that size, for it is found that in the winter of 1861 they took the 12-inch shafts of the steamboat "Glen Cove," that had been in New York waters at one time, and as they had no steam hammer large enough for the work, with fifty men at a time to splice and weld them into one shaft, and turn it down to 9 inches, it occupied them 45 days of day and night work.

This was about the condition of the iron-rolling mills in the Southern States fitted for heavy work at the commencement of the civil war. There were a few other mills of small capacity in Virginia at the same time, but as they were located in the contested field of military operations when the war was in progress, they were of limited service to the Confederate States.

The Secretary of the Navy of the Confederate States in May, 1861, made inquiry of some of the owners of these rolling mills if they could produce the heavy plate iron for armor, and was informed by the owners of the western mills that "they could not roll such heavy work," and that "they would not undertake to roll iron for the Confederate States in the then condition of the country in which the mills were located." The Cumberland mill furnished considerable manufactured iron, other than armor plate, for the southern interests for several months at first, but that service ceased from military necessity. During the same year the Navy Department endeavored to get parties to establish an iron-rolling mill at New Orleans, La., a provisional appropriation having been made toward the object of $10,000 by the Confederate Congress, but the tools and machinery for such a plant were not to be obtained at the time. So it will be seen the only American rolling mills the Confederate States could depend upon to manufacture the armor plate for them were the Tredegar Iron Works and the Atlanta Rolling Mills. During the fall of 1861 the Tredegar Iron Works and the Armory Rolling Mill were united under one management, and their capacity was later increased for making plate iron.

The Gate City Rolling Mill at Atlanta, Ga., was situated to the southeast of the city, one mile from its center, and on the line of the Georgia Railroad. It was the most extensive establishment of its kind south of the Ohio River. It had originally six puddling and eight heating furnaces, and two teams of rolls, and was owned at first by L. A. Douglass of Atlanta. When in active operation there were about 150 men employed. They produced during the war period some railroad iron during cases of emergency.

The owners of this armor plate mill were in November, 1861, Messrs. Schofield & Markham, and at this time they began to make alterations in the mill necessary to produce the armor plate for the naval vessels of the Confederate States. The first of the product was used during that winter on the ironclad "Mississippi" then building by N. & A. F. Tift at New Orleans, La. These plates were 2 inches thick, 7 inches wide, and 10 feet long, made from old rails, and cost at the mill 6¼ cents a pound with the bolt holes drilled. This vessel while in a partially completed condition was launched but a few days before Admiral Farragut entered the city of New Orleans in April, 1862, on which occasion she was set on fire and destroyed. It was supposed at the time, if the vessel had been completed, that Farragut would have had a very formidable antagonist to deal with. This rolling mill also furnished the armor iron for several other southern ironclads, though none that gained so much prominence as the "Tennessee," that was captured in the engagement in Mobile Bay on August 5, 1864. This vessel was built at Selma, Ala., and the wooden walls of the casemate that were 25 inches thick were covered with the plates of iron armor 7 inches wide and 2 inches thick on the forward and after walls, to a thickness of 6 inches, and 5 inches on the side walls of 2-inch and 1-inch thick plates, and all fastened with 1¼-inch through bolts, similar to the other vessels. This Atlanta mill had one great advantage in being near to the extensive fields of coal and iron ore, located in northern Alabama; and again for about three years in freedom from interruption of operation, in being outside the zone of military contest. Within a radius of one hundred miles, of which Atlanta was the center, lay the industrial plants during the last half of the civil war that served the Confederate States with their munitions of war that were made at home. There was a rolling mill started at Selma, Ala., in 1863 by the Confederate States government that made the lighter weight of iron for the Navy Department. The blooms came from the furnaces of northern Alabama.

The Atlanta mill continued in the service of the Confederate States, making the specialty of armor plate, until some time in the summer of 1864. It was destroyed by fire on the evacuation of the city by the Confederate army. An official photographic view of the ruins of this mill shows it to have been one covering a large surface of ground, and having been equipped for producing a large amount of plate iron and iron rails. It was no doubt the mainstay of the Confederacy in the manufacture of their domestic armor plate. There was a small amount of iron armor that was successfully run through the blockade during the last year of the strife.

There was an iron-rolling mill at Shelby, Ala., that began operations in 1862 or 1863 in rolling light-weight iron plates, and continued its manufacture for the Southern Confederacy until the works were destroyed by the Union forces in 1865. There are no data showing what this iron was for. It is claimed that the armor plates for the "Tennessee" were rolled at this mill, but of this there seems to be a doubt; for a search of such official records of the Southern Confederacy as are available at this day make no mention of the Shelby mill. J. L. Porter, the Naval Constructor of the Southern Confederacy, in his Annual Report of November, 1864, says: "In consequence of the loss of our iron and coal regions, with the rolling mill at Atlanta, our supply of iron has been very limited. The mills at Richmond are capable of rolling any quantity, but the material is not on hand." Col. Gorgas, Chief of the Ordnance Bureau of the Army, says: "We began in 1861 without an arsenal, laboratory, or powder mill of any capacity and with no foundry or rolling mill except at Richmond; . . . but we created before the close of 1863, literally out of the ground, foundries and rolling mills at Richmond, Selma, Atlanta, and Macon." As neither one of these official reports of 1864 makes any mention of the Shelby iron mill, nor does the Ordnance Bureau of the Navy Department name its existence, it is not improbable that this mill began the rolling of some heavy iron plate after the Atlanta mill ceased operations. There may have been some armor plate sent from Atlanta to Shelby for safe keeping, at the time the Union forces were nearing the former city.

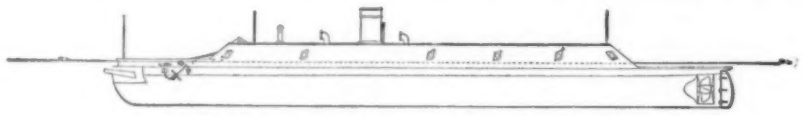
These mills were subjected to many delays in the manufacture of this armor from one cause and another. The one that provoked the most delay was from the want, at times, of labor for the taking out of the ore from the mines, as well as the skilled labor at the furnaces, and in the rolling mills. The greatest void in the mills owned by the Southern Confederacy was in the want of able assistants to the heads of the various bureaus; those who had an intimate knowledge of the manufacturing part of the bureau, and at the same time were able to direct a body of men and lay

out the work for them to the best advantage, and thus relieve the head of the bureau of a vast amount of detail supervision. While in 1862 the unsatisfactory results of the operation of some of the mills came from the partial want of proper machinery and tools to operate them to the best advantage, at a later period the scarcity of skilled labor to operate the plants was felt most keenly. Then after the spring of 1864 the Union army began to make their presence felt in Georgia and Alabama, and this drew upon the labor at home for the increase of the army, that was the means of closing up many industries that were operated in that section for the Confederate cause. Besides, many of the mechanics were foreigners, who having no personal interest in the war, deserted their employment when they found that the sphere of military activity was closing in about them.

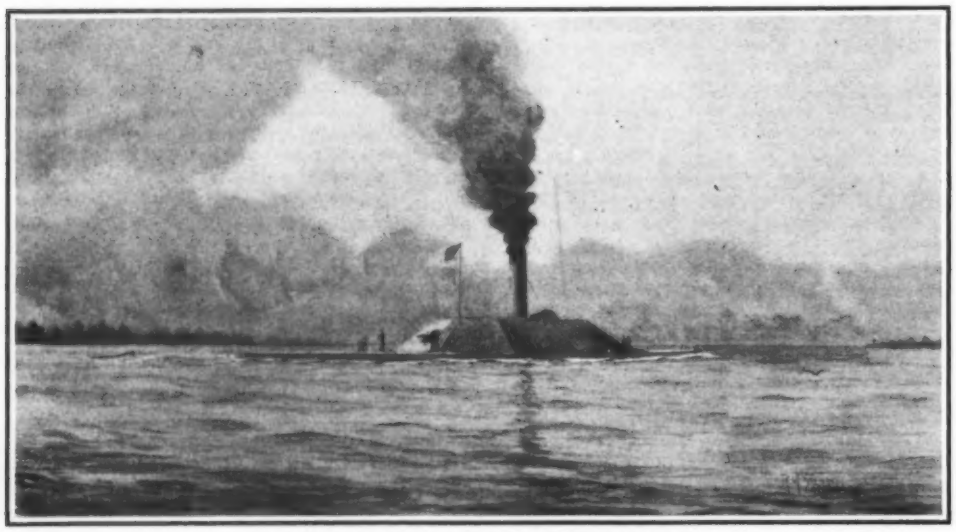
When the "Merrimac" or "Virginia" was rebuilt in 1861-1862, the Tredegar Iron Works rolled the plating for the armor of the casemate of the vessel from old iron rails. These plates were 8 inches wide and about 10 feet long; this was the greatest width of this iron they could then produce. One-third of this iron was but one inch thick, as at first one-inch-thick iron was as heavy as could be punched at the mill, but the balance was two inches thick. The two-inch iron was laid on the casemate in two courses, the inside course laid longitudinally, and the outer course nearly vertical; the one-inch iron being laid in two courses next to the timber backing. The plates were fastened in place by 1⅝-inch countersunk-head iron bolts secured by nuts and washers on the inside of the wooden backing. This vessel was 262 feet 9 inches from the stem to the after side of the stern post, and from the stem to the forward end of the shield was 29 feet 6 inches. From the tiller to after end of the casemate was 55 feet, and the length of the shield was 178 feet 3 inches. The framing of the shield was of yellow pine 14 inches thick, bolted together and placed at an angle of 35 deg. Outside of this a course of 4-inch pine plank was laid and fastened, fore and aft, and outside of this there was a course of 4-inch oak plank laid up and down. All three courses were calked. Upon the outside of the latter course was laid the iron armor.

The Tredegar Iron Works subsequently rolled considerable of this heavy iron plate for other southern ironclads, though not to the extent of the production of the Gate City Rolling Mill. The three ironclads constructed at Richmond, Va., in 1863 had their armor rolled at the Tredegar Iron Works, as well as the armor for the "Albemarle" that was completed in 1864. These vessels were all of the same type as the "Merrimac" with the exception of the submerged ends of the vessel.

As the experiments made to determine what the armor for the "Virginia" or the "Merrimac" should be, and as they were planned at an early stage of the war, when there was but little known on the subject of iron armor in this country, it will be of interest to know what Comm. John M. Brooke, Chief of the Ordnance Bureau of the Navy Department of the Southern Confederacy, said in 1863 of these experiments: "I was directed by the Secretary to fire at iron plating with the guns at Jamestown Island. We constructed first a target from a plan proposed for the 'Merrimac's' shield. The wood was about 24 inches thick, the iron 3 inches thick, consisting of 1-inch plates three deep; the surface target was inclined at an angle of about 30 deg. with the horizon. At a distance of about 300 yards, an 8-inch solid shot with a charge of 10 pounds of powder penetrated the iron, and entered five inches into the wood; and this was the case with several shots, some seven or eight. It was then thought proper to increase the thickness of the iron to 4 inches. A new target was constructed, of which the plates were 2 inches thick, forming two layers. Eight-inch shot with 10-pound charges, and 9-inch shell weighing about 70 pounds, with 10-pound charges, were fired against the target. The outer plates were shattered, the inner ones were cracked, but the wood was not visible through the cracks in the plating. The original plan contemplated the first plating described, but this experiment indicated the necessity of increasing the thickness of iron to 4 inches, which was done. The 11-inch shot of the 'Monitor' would have penetrated the shield of the first description, I think, very readily; but it did not penetrate the 4-inch shield in the battle. These were the experiments." He also mentions some experiments made in February, 1863. "The 8 inches of iron was composed of four layers of plates, each plate 2 inches thick and 8 inches wide and about 8 feet long. The layers of plates were placed alternately vertical and horizontal, and were bolted to 22 inches of timber backing, the whole supported in rear by clay, against Drewry's Bluff. It was in a ditch so that the top of the target came upon a level with the ground, and then the ditch was filled up in the rear, making it a solid mass. The charge of this gun was 25 pounds of powder. The gun was a rifle, and the bolt was of wrought iron weighing 140 pounds. It broke three layers of plates, so that pieces came out, and broke the remaining plates, and pushed them firmly in the wood, so that the fibers of the wood were projecting in the cracks. The target was about 200 yards off."



CONFEDERATE STEAM FRIGATE "VIRGINIA."



THE CONFEDERATE RAM "ALBEMARLE."

Prepared from authentic photographs and measurements of the original vessel.

The only *iron-hull* armored war vessel in the Confederate States navy was the "Atlanta," that was captured on June 17, 1863, in an engagement with the monitor "Weehawken" in Warsaw Sound, Ga. This vessel was originally the blockade runner "Fingal," that was altered by cutting her down to the main deck, which was increased in width about 16 feet amidships, by building out solid with timber, 8 feet on each side, and carried tapering down the sides of the vessel about 9 feet, and decreasing in width and height toward the ends of the vessel. Her reconstructed dimensions were 204 feet extreme length, breadth 41 feet, and loaded draft of water 15 feet 9 inches. Her original loaded draft was 11 feet. The casemate built on this wooden structure was covered with two layers of rolled-iron plates 2 inches thick and 7 inches wide, and secured in place by 1¼-inch countersunk-head through bolts, similar to most of the casemate ironclads of that period. She was also fitted with an iron ram. This vessel had the largest and most powerful engines of any of the southern ironclads, but the shape of the altered hull was the weak point in the vessel. The iron armor on the casemate must have been of very poor material, for in a survey made of the vessel just after her capture, there is this reference in the report of her armor: "The armor appears to have been made of English railroad iron rolled into its present shape. In some of the fractures it has broken off almost as short as if it had been cast iron." This was the product made from some English railroad iron, that was run through the blockade, and rolled into armor plate. It was evidently poor material for the purpose.

There were five or more of these ironclad rams during the first two years of the contest, that had their casemates covered with railroad iron, most of the rails being taken from some line of railroad that was but little used at the time, or a line of railroad that was on disputed territory, and between the two opposing armies; or, as in the building of the "Louisiana" at New Orleans, La., where the builder of the vessel bought 500 tons of new rails that had been "appropriated" by the Confederate States government from the cargo of a blockade runner. These rails when used as an armor on the casemate of a vessel, had six or eight holes drilled in each rail, for the bolts to fasten them in place on the backing.

The last year of the rebellion appears to have been the most busy one for the Confederate Navy Construction Bureau, for the Secretary of the Navy in November, 1864, in his Annual Report, says that there were at the time thirteen steam vessels either launched or nearly ready to be placed in the water, that were waiting for the whole or a part of their intended armor, and that the whole estimated weight of the iron armor to complete the vessels was 4,230 tons. The military interruption to the working of the iron mines and the loss of the Atlanta Rolling Mill was the reason assigned as the cause of this scarcity of iron armor plate in the Southern Confederacy. It was intended in most of these vessels to increase the thickness of the armor to 6 inches, making it either three courses of 2-inch iron or two courses of 3-inch iron to withstand the power of the improved gun.

There was one so-called ironclad Confederate ram, during the early days of the civil strife, named "Manassas," that may be noted with details as being the first of that class of vessel in service during the rebellion, if not the first ram in service in any steam navy in the world. This vessel had a very short and checkered career. She was originally built at East Boston, Mass., in 1855 as a wooden-hull tugboat for ocean work for George Kimball and others of Boston. She was launched and known during the days of her peaceful service as the "Enoch Train," and considered the fastest propeller tugboat on the coast. The hull dimensions were 128 feet by 26 feet by 12.6 feet, and the motive power was a pair of vertical condensing engines, each having cylinders 36 inches by 32 inches stroke, and operating twin screws. The lines of the hull of this vessel are still in existence. She remained in service about Boston for nearly four years, when she was sent to New Orleans, La., to engage in towing vessels to and from the passes of the Mississippi River. When the civil strife got under full headway in the Southern States, the act of the Confederate Congress in recognizing privateering was taken advantage of by many persons in that section of the country, among them being several members of the Merchants' Exchange of New Orleans, who formed a stock company having a capital of $100,000, and purchased this vessel, to be used for the protection of the property of New Orleans only, and for warlike purposes. Otherwise, it was a war vessel for State purposes only. The vessel was placed in the hands of a shipbuilder in May or June, 1861, for alteration to an ironclad ram. The deck houses were removed, and a turtle-back shaped frame, built of 17-inch square oak timber, placed close together, and having a height at center of length of vessel about 7 feet in the clear, diminishing to the ends, covered the main deck. The hold was filled in solid with heavy timber for nearly 20 feet from the stem, and a cast-iron ram fitted in place on the bow of the vessel.

There appears to be more than one opinion held as to the form of iron covering the turtle back of this vessel. Commander J. K. Mitchell, C. S. N., commanding the Confederate fleet at New Orleans, said, "iron in her very thin, not more than 1½ inches"; and Lieut. A. F. Warley, C. S. N., who commanded the vessel during the engagement with Admiral Farragut's fleet at New Orleans, said, "a tugboat that had been converted into a ram, covered with half-inch iron, and had a 32-pounder carronade. Her crew consisted of 35 persons, officers and men. She was perforated in the fight by shot and shell as if she had been made of paper." James Brown, who was an acting master on the vessel, says to the writer: "They put a very heavy timber frame over the main deck, turtle shape, and covered all this over with railroad iron." J. A. Chalaron, the present secretary of the Louisiana Historical Association, and who was a resident of New Orleans at the time of the rebuilding of the vessel, says of the armor: "She was covered with rolled wrought-iron rails taken from the Mexican Gulf Railroad running from New Orleans to Proctorville on Lake Borgne. The rails were about 2½ inches wide

by 1½ inches thick." This undoubtedly establishes the fact of the vessel being covered with railroad iron. At first she had two smokestacks, but when the Navy Department owned her she had but one smokepipe. What gave her such a reputation for her short career was the night attack made on the Union fleet at the head of the passes of the Mississippi River on October 12, 1861, when she rammed two of the vessels then lying at the station and doing herself as much injury as the vessels she attacked. When her ram struck the U. S. S. "Richmond," it made a break about 5 inches diameter and caused a leak that made it necessary for the vessel to be taken to Key West, Fla., for permanent repairs. Just after this attack she was purchased by the Confederate Navy Department. Her only value lay, when handled with skill, in her offensive power as a steam ram, as was demonstrated in the engagement with Admiral Farragut's fleet before New Orleans, where she was finally run ashore and destroyed by the "Mississippi" of the Union fleet.

No less an authority than Spears's "History of Our Navy," in vol. 4, page 128, says of the "Manassas": "For motive power she had one compound engine and two screws, the high-pressure cylinder working one shaft and the low-pressure the other." So far as the type of engine is concerned this is an error, for the compound propeller engine was not built in this country until 1864, when they were constructed for the steam yacht "Octavia."

(To be continued.)

# ELEMENTS OF ELECTRICAL ENGINEERING.—IV.

## ARC LAMPS.

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Continued from Supplement No. 1660, page 270.

THE significance of the word "arc" is not altogether apparent. Davy introduced the expression, when he first produced the electric light a century ago; he observed that the path of the current from one electrode to the other was not straight, but crescent shaped. Though his source of current was batteries only, yet he employed a large number to operate a single light; as compared with modern practice he used an abnormal potential. A separation between electrodes of an inch or two was probably possible with his apparatus, and the curved path of the current might readily have approached the arc of a semicircle. Separation between the carbons of ordinary old style "open" arc lamps is very much shorter, and the "arc" is more nearly a ball, its real appearance being disguised by the intense incandescence of the points, but the greater separation of the carbons in the present "inclosed" lamps again reveals the real path of the current.

Davy's electrodes were made of wood charcoal, and at best could have lasted but a few minutes. Later, Foucault, having the advantage of methods of making artificial coal gas, cut the pencils from the retort coke or carbon. Though containing slag and other non-conducting substances, from some of which the heat of the arc liberated poisonous gases, this denser material was highly refractory, and a pair of the pencils, or "carbons" as they were soon called, would last for several hours. This permanency allowed scientific study of the operation of the arc, and brought out various facts and theories. One carbon was observed to be hotter and to burn about twice as fast as the other; it burned tapering, but the very end, instead of being pointed, was hollowing; this "crater," so called, is small, but its temperature is so high, perhaps 3,500 deg. C., that it emits the greater part of the light. The other carbon is only about half as hot—indeed, metal can be substituted for it—and burns pointed; this point may constantly be receiving deposits from the other carbon.

Heated vapors are really conductors of electricity. Fires in central stations, resulting from short-circuits, owe their chief ferocity to the conducting properties of vaporized copper. It is believed that between the heated carbons of an arc lamp there is the vapor of carbon; the presence of oxygen necessarily results in some combustion, so the carbons slowly disappear. Usually the light is desired below the lamp, and for that reason the hotter carbon—found to be the positive—is selected to be the upper one, thereby throwing its light downward; but in searchlights and stereopticons, the carbons may be disposed horizontally or at right angles to each other; or, for giving the best distribution for particular places, say for a drafting room, the hotter carbon may be the lower, to direct the light upward, against a white ceiling and there be reflected downward in a highly dispersed manner.

Some speculations have been made as to the cause of the resistance of the arc. As far as the vapor alone is concerned, the resistance would appear to be only about 0.2 ohm, and yet the actual resistance encountered is equivalent to from 2 to 5 ohms. One theory holds that the arc is the seat of a counter electromotive force, the other that the resistance is purely ohmic; the latter idea seems to be most generally accepted: in reality it seems about as difficult to prove the one as to disprove the other theory.

As for the particular amount of energy consumed in an electric arc, there is some opportunity for variation in the number of volts and amperes, yet with the same number of watts the light is about the same. Gramme used about 30 volts and 15 to 25 amperes per lamp, but Brush found favor with 45 volts and 10 amperes. Weston adopted Gramme's practice, while Thomson followed Brush's. The lower potential results in an arc only about 1/32 inch in length, which emits a continuous hissing sound, but the light is very white, inclining toward the yellow, while the higher potential and less current allow an arc nearly ⅛ inch in length, noiseless, but quite bluish in color. While a short arc is always hissing, a long one can be made to hiss by sufficiently increasing the current. Higher potentials would result in still longer arcs; by concentrating the entire voltage of a 40-light machine in a single lamp, Brush obtained an arc two feet long. Economy in the cost of conductors argues for the

Fig. 17.—Direct and Alternating Current Arc Lamps for Use on Constant Potential Circuits.

adoption of the lesser current, and reliability of operation of the mechanism of the lamp is enhanced by the latitude of the longer arc. Open arc lamps are often operated at 45 volts and 6½ amperes, giving 1,200 "nominal" candle power, while the 10-ampere lamps are estimated at 2,000 nominal candle power. Open lamps operated by alternating currents run rather unsatisfactorily; 30 volts and 13 amperes seem to be about the best values, but the noise produced by the rapid heating and cooling of the air in the vicinity of the arc is disagreeable, and for some places, intolerable. The modern inclosed lamps take, with direct current, about 80 volts and 6½ amperes; with alternating, 72 volts and 7½ amperes. Since the noise varies about as the square of the current, the latter sort are a considerable improvement over the 13-ampere open lamps, and are fairly acceptable—certainly as far as street lighting is concerned.

The first arc lamp mechanisms were of delicate clockwork construction, entirely out of keeping with the poor quality of carbons available. The train of wheels was usually placed in a frame located below the arc, where the accumulation of dust readily interfered with the movement. Unnecessarily, the construction was further complicated by making the lamps of the "focusing" sort, i. e., having the arc burning in the same location. Even Gramme's lamps, though having the mechanism above the arc, retained the other two features of considerable clockwork, and of feeding the bottom carbon upward at a certain rate, about half an inch an hour, and the upper one downward about twice as fast, to meet the unequal rates of burning. Brush's type of lamp, compared with these, was a marvel of simplicity and reliability; in the first place there was entire absence of clockwork, a hollow brass rod instead of a rack being used for holding and guiding the carbon; this rod passed through a loosely fitting washer in the box over the arc; when allowed to rest in a horizontal position, the rod was therefore free to slide up or down without any interference; to the core of a solenoid was attached a hook that could lift on one side of the washer; when sufficiently energized with current, this solenoid would lift its core, tilt the washer, thereby engage the rod, and further movement would separate the carbons and establish the arc. Whatever the length of carbons, they normally rest in contact, and will be ready to separate by the action of the current. A suitably diminished current would allow the washer to be tripped and allow a slipping through of the carbon rod, and re-establishment of normal current. To prevent undue slipping, Brush filled these brass tubes with glycerine, and suspended in it from the protecting "chimneys" over the lamps loosely fitting pistons, so that the rods could not move without waiting for the glycerine to ooze through the narrow spaces. Simplicity was further provided by omitting all attempts at holding the arc in one place, for the lower carbon was fixed, gravity feeding the upper carbon downward, as permitted by the solenoid, at a rate to compensate for the burning of both.

Such a lamp works perfectly, if it is the only one in a circuit; for a greater or less length of arc will so vary the resistance as to make the current vary in inverse manner, and release or raise the clutch. Two or more such lamps in series will not operate at all well; for though the same current may pass through them, there is nothing in the mechanism to compel each to draw the same length of arc. If the

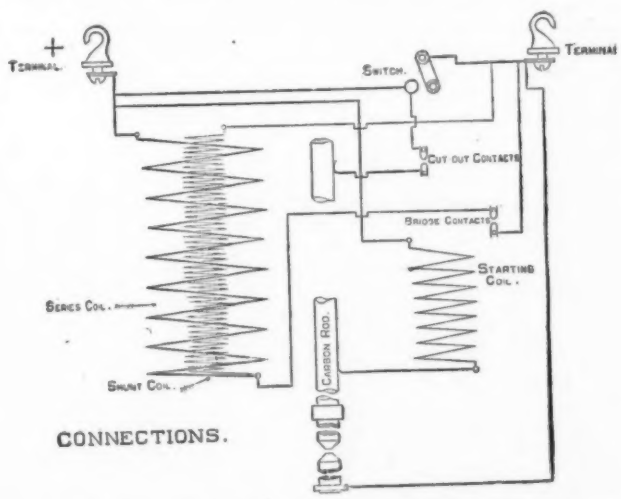



Fig. 16.—Diagram of Circuits of Thomson-Rice Non-Infringing Arc Lamp.

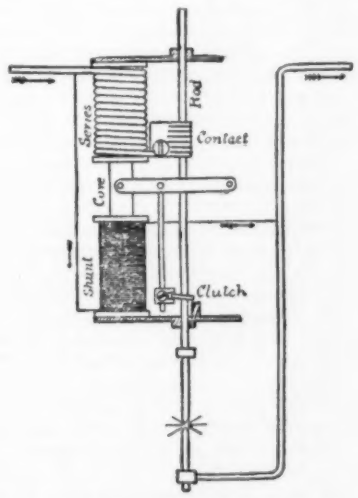



Fig. 15.—Diagram of Circuits of a Differential Arc Lamp.

regulator on the dynamo was really capable of keeping the current constant, the entire possibility of proper feeding of the carbons would be forestalled, for confessedly a variation in the current is essential to such operation; the current would keep on burning the carbons further and further apart—though with no two arcs of same length—requiring more and more voltage, until the maximum capacity of the dynamo

was reached. Some arc would then be ruptured, thereby breaking the entire circuit, all the carbons would fall, and constitute almost a short circuit for the generator at the moment when the regulator was in the position for maximum voltage. Some such accident as stalling the engine, throwing off the belt, or injury to the windings or commutator would surely result.

Possibly, Brush's greatest invention, or adaptation, was made in 1878, when he adopted the practical, yet simple, method of avoiding this obstacle to series arc lighting. It consisted in putting double windings on the solenoids of the lamps—one of coarse wire in the main circuit as theretofore, the other of many turns of fine wire connected as a shunt across the terminals of the lamp. This latter had a resistance of about 500 ohms; therefore, at an average working value of 50 volts, about one-tenth of an ampere was sidetracked through this circuit. Since this current does not go through the arc, it represents a direct loss as far as illumination is concerned, but for operating any desired number of lamps in series, it is an essential and marvelously effective device. Its efficacy lies in the fact that it is electrically connected in opposition to the action of the current in the main winding; the combination, therefore, constitutes a differential winding, and such lamps have consequently been designated as of the "differential" type. In the Brush lamps the shunt coils were wound on top of the series, but some makers have done just the opposite, while still others have preferred to make the coils entirely separate, though acting through suitable levers upon the same mechanism.

To make these two circuits clear a diagrammatic representation is shown in Fig. 15. Incidentally the scheme of the Brush "ring-clutch" is also included. In order for the upper carbon to be the positive, current must flow in the directions shown by the arrows. The soft iron core is a very loose fit in the solenoids and extends about half way through each. A thin sheet copper strip, cut with many slits, makes a good electrical contact with the rod without depending upon the guides or causing undue friction. With no current flowing, the core rests upon a stop, and the clutch is horizontal; the carbon rod is therefore free to slide and the carbons themselves are in contact. As soon as the main current flows it energizes the upper solenoid, sucks the core upward, tilts the clutch, engages the rod, thereby separating the carbons and establishing the arc. Thus far the operation is identical with the earlier lamps, and such as are now extensively used on independent circuits. As soon, however, as the carbons are separated, a certain difference of potential must exist between them to maintain the arc—with 10 amperes it being about 45 volts for a separation of 3/32 inch—and this potential at once sends the small current through the shunt circuit, and its pull prevents the carbons from being drawn further apart and making a longer arc. When the carbons have burned off a little, somewhat more than 45 volts are required, and this higher potential sends a little more than normal current through the shunt coil, overpowering to a greater extent the action of the series coil, and causing a release of the clutch. The shunt current is continually trying to bring the carbons closer together, but the main current is trying to separate them, and the balance between these two forces exists with only one length of arc. By means of an adjustable spring to assist, or oppose, the action of one of the solenoids, the lamp may be adjusted to any desired length of arc, and after the shunt coil has acquired its final temperature and resistance, the variation in potential will not exceed 5 volts, and the successive feedings of the carbon will be in steps of not over one one-hundredth of an inch.

Though not shown in the diagram, another device in the lamp is essential to the maintenance of the circuit as a whole; a fault in one lamp must not be allowed to interrupt the operation of the rest. Failure of the rod to slide when the clutch is released may result from accidental bending or accumulation of dirt, or the carbons themselves may be sufficiently burned out, and the lamp require "retrimming." Brush added a small electromagnet with two windings, one of fine wire connected in the shunt circuit, the other of coarse, but out of circuit unless the armature was lifted. A retractive spring normally held this armature against its back stop. If a considerably longer than normal length of arc was drawn, say ⅝ inch or over, about 75 volts would be required; this potential would then send nearly double the ordinary current through the shunt circuit, lift the armature of the "cut-out" magnet just mentioned, and short circuit the lamp; the shunt circuit immediately ceased to be energized, but the main current then flowing through the other winding would retain the armature and keep the circuit closed. As soon as the extinction of a lamp is noticed, the trimmer closes another switch which makes the short circuit sure, remedies the fault, if possible, and reinserts the lamp in circuit. Aside from the exhaustion of carbons, about the only troubles with arc lamps are the wearing of the rods and clutches and burning out of the shunt coils.

Brush secured a patent on the ring clutch, but the Weston Company infringed upon it, and in the litigation that followed he lost it, the courts claiming that the device was too simple to constitute the subject of a patent. On the differential winding the patent was more vital, and its ownership meant exclusive control of series arc lighting. As expected, infringement and attack at once began, the Thomson-Houston Company being logically selected for prosecution. While the matter was still unsettled in the courts, the defense adopted a double expedient—its management began quietly buying all the Brush Electric Company's stock that was on the market, while Prof. Thomson, with his first assistant, Mr. Rice, invented a non-infringing lamp. The specification of the Brush patent was clear and apparently proof against circumvention, "both windings are in use at the same time." A close study will, however, bring out a clear distinction in the functions of the two coils: the series is needed for starting only, while the real feeding of the carbons is performed by the varying current in the shunt. If these two functions could be completely divorced—that when the series coil was in use the shunt was not, and that when the shunt coil was doing its work, the series coil was cut out, the technicality of the patent would be avoided. This was what Prof. Thomson actually did. Since the series coil can exert merely a constant pull, with the starting of the arc as its principal function, he limited its use to that initial purpose only, and replaced its pull thereafter, in the running of the lamp, with an adjustable spiral spring. An additional magnet was needed for cutting the series coil out of use as soon as this one act was accomplished. Since the spring acted in the direction to separate the carbons, the lamp presented a unique appearance when idle, for the carbons were then separated, and it was not apparent how the current could ever jump the gap and complete the circuit. Of course the carbons must touch before the current can flow, and this condition was properly provided, as will be explained.

A diagram of the circuits of the Thomson-Rice lamp is given in Fig. 16. The large zigzag lines on the left represent the series coil, the finer ones the shunt coil within; on the right is the "starting" coil; "bridge" contacts are associated with the action of the latter, while "cut-out" contacts depend upon the motion of the main armature over the series and shunt coils. The main magnet has paraboloid shaped ends, and the armature pierced with two large holes is pivoted so as to be capable of considerable up and down movement just above them; of the two cut-out contacts, the lower one is fixed, and the upper one is on the same lever as the armature; and the fulcrum being still further to the right, the extreme downward motion of the armature will bring these two contacts together; the upper of the two bridge contacts is fixed, and the lower one is always held in contact with it by the tension of a spring, except when overcome by the action of the "starting" electromagnet. With this understanding of the mechanical arrangements, the electrical circuits can be comprehensively traced. Arriving at the positive pole there are three possible paths for the current. One is through the switch, if closed; combined with the switch is a cam that depresses the main armature, and releases the clutch, so that a trimmer will have no trouble in sliding the carbon rod. If this switch is open, the carbons are separated, yet the current has still a path through the lamp; it can flow through the series coil, and by the bridge contacts reach the negative terminal. The armature is thereby pulled down, releasing the clutch and allowing the carbons to come into contact with each other; as soon as this happens, the third path is provided, i. e., from the positive terminal through the starting coil to carbons and on to the other terminal; but the energizing of the starting coil separates the bridge contacts, and breaks the circuit through the series coil; no appreciable spark results at this rupture, for the current has an alternative path; under the action of the spiral spring the armature then flies up, re-engaging the clutch, separating the carbons, and establishing the arc. Thus the series coil has done its part and is cut out from further use. At a convenient place, really at the bottom end of the series coil, the shunt is attached; by this, the two windings become one, but the few turns of the coarse wire make only a small addition to the many of the fine shunt wire. As soon as the arc has been established, the difference of potential between the carbons sends a current through this shunt circuit; variations in the length of the arc, requiring similar variations in voltage, will be corrected by the action of the shunt as in the differential lamp. An extreme length of arc, say ⅝ inch or over, resulting from burned-out carbons or from failure of the rod to slide, will require upward of 75 volts for its maintenance; enough current will then be driven through the shunt circuit to attract the armature downward until the cut-out contacts meet; this act short-circuits the starting coil, again allowing the bridge contacts to complete the circuit through the series coil. The arc is at once extinguished, the shunt coil ceases to be active, but the armature is securely held by the pull of the current in the series coil. Though some words and time have necessarily been used in the description of the real shifting of the circuits, it is almost instantaneous.

Aside from the ingenious devices for dodging the patent, this type of lamp has some actual advantages over the differential lamp. The first of these is that the likelihood of starting the dynamo is increased. Arc circuits are often 15 to 20 miles in length, yet unless the resistance of the circuit is low, the series dynamo will not excite its fields; forty or more sets of carbons in series constitute an appreciable resistance, and if some bit of non-conducting material be on the end of one, it may, in case of the latter type, interrupt the whole circuit, with considerable delay in locating and removing the fault. With the Thomson lamp there is a good metallic circuit through all the lamps, at start, and when the carbons do drop, their ends are pulverized into good electrical contacts. Even if the rod in one lamp is stuck, the rest of the lamps will suffer no interruption. Again, the resistance of the series coil is not encountered in the normal running of the circuit; this makes a slight economy of working over the differential lamp. Finally, the latter type is necessarily adjusted to a critical value of the current, when just the right balance between the opposing forces of the two coils exists; the other type is not so sensitive, for the current may vary several amperes below normal without extinguishing the light. Certain it is that though the Brush Company lost its suit and a controlling interest in its own stock, the Thomson-Houston Company continued to make these celebrated "M. & K." lamps until within a few years.

It seems that the real ground for the loss of this patent was the earlier invention of the differential lamp by Lacassagne and Thiers, in France. These experimenters used it in single lamps only. Brush recognized the principle as the one to make the series operation of a large number of lamps possible. Brush invented and maintained the patent for the double carbon lamps, whereby when one set was burned out the second set was automatically brought into use; the device was as simple as the rest of his inventions—he only made the clutches slightly different, so that one would lift its rod before the other, the arc forming at the separation of the second set. When this set was burned out, the slight further relaxation of the solenoid would allow the second set to begin feeding. This invention was especially applicable to all-night lighting, for the two sets of carbons would last about sixteen hours—sufficient for the long winter nights. Brush also improved the quality of the carbons and cheapened their cost; he patented the device of copper plating them to reduce their resistance.

For half a century it has been known that with a reduced atmospheric pressure a longer arc could be sustained than was found under ordinary conditions, and with an increase in the potential, a much smaller current would give equally good illumination. Various impractical devices, involving the use of air pumps, or other such suction appliances, were proposed to utilize this idea. A practical realization of some of the advantages of the "inclosed arc" was first exhibited in Chicago in 1893—the invention of L. B. Marks. It had some obvious defects, and these were so slowly overcome that popular approval was delayed for several years. First, the mechanical construction was bad, the carbon being held on a rod, like the open arcs; counting in the restricted opening in the top of the globe, there were thus three guides, and a crook in the rod or carbon or frame would prevent the proper feeding. This defect was remedied by omitting the rod altogether, and letting the clutch operate directly on the carbon itself—the considerable separation and smoothness of the carbons readily allowing this expedient to be successful. For cheapness, it was desirable to make the globes as small as possible, and small ones really lasted longer than large ones; but qualities of glass and porcelain that were hard enough to withstand the heat without softening would crack, and those that would not crack would soften by the action of the heat. When the proper quality of material was found and the globes made of the right shape, and the lamps subjected to practical use, troubles were experienced with the carbons; if too hard, they would flame, and if too soft, they would smoke the globes. European "soft" carbons with central portion or core of still softer grade than the exterior, were found to be the best. The ordinary sort for the 6½ and 10-ampere open lamps is made from mixtures of pulverized charcoal and coke mixed with molasses or sugar syrup, formed in iron molds and then baked at almost white heat for ten to twelve hours. The soft quality is made from lamp black, and it is only within a few years that American firms have adopted European methods of manufacture.

After the General Electric Company had purchased the Marks patents and definitely discarded the open arc, there was proof that the inclosed arc had overcome all its early obstacles. Several important advantages are gained with this present standard type of lamp. The partial vacuum, due to the heat, allows a longer arc, and that becomes the main source of light instead of the tips of the carbons, and the lower temperature of the latter together with the meager entrance of oxygen into the inclosed space so diminishes the combustion that even initially short carbons will last from 100 to 150 hours. Necessity of trimming once in a week or two, in place of daily, represents a great saving in attendance. Again, the reduced current makes possible the satisfactory operation of lamps for extensive interior use in multiple on the same circuit with incandescent lamps. With a given allowance loss in transmission, the size of the copper wires required varies as the square of the current, consequently a 6½ ampere lamp would require only about 40 per cent as large wires as one consuming 10 amperes; the open lamp could utilize only about 50 volts out of the total 110 or 115 ordinarily existing on a constant potential circuit, the rest being wasted in a rheostat; with 80 volts, as needed in the inclosed lamp, only 30 would be wasted, the watts being only 200 as compared with 600; the economy is therefore much greater, and the reduced size of rheostat, or resistance, makes it an inconspicuous adjunct. Some resistance is always needed in series with such lamps, otherwise at the start there would be a disastrous rush of current, and in case the clutch failed to lift the carbon at all, a short circuit would exist. In regular operation, the arc is so variable as to have constant need of the steadying effect of some additional ohmic resistance. Single lamps connected across 110-volt mains require the series winding alone in their operating mechanism; two in series on a 220 or 250-volt circuit, or four in series on a 500-volt power circuit, would need the differential winding. Alternating currents successfully light inclosed lamps; if for multiple use, on 104 to 110-volt circuits, a reactive, or "kicking" coil, replaces the resistance coil used with the direct-current lamps; such a device generates a counter-electromotive force, and though it creates an undesirable lag in the phase of the current, it minimizes the energy of operation. The cores of the solenoids of such lamps must be laminated or composed of a bundle of fine wires, instead of being solid, or they would become ruinously hot from the flow of eddy currents. Fig. 17 shows views of standard direct and alternating current "multiple" lamps with the casings removed to expose the mechanism.

Within a year, a new arrival among arc lamps has come from Germany. It is called the "flaming" arc. Heretofore, the flame has carefully been avoided, and such voltages, current, and qualities of carbons adopted as would be free from it. In exterior appearance the lamp is rather longer than the inclosed type, and has a nearly spherical opal globe, that allows the free entrance of air at the top. It is essentially then an open lamp, and requires new carbons every 10 or 12 hours. Both carbons move downward at a very acute angle with each other—in this respect resembling some of the curious lamps made a quarter of a century ago. The two supporting side rods are electromagnets, and their action "blows" the arc between the carbons into a deep U. By this action, the light-giving area is so much increased that with no greater expenditure of energy than is used in the old open lamps, about five times as much illumination is secured, the makers claiming 10,000 to 12,000 candlepower. The otherwise bluish tinge of the arc is replaced by yellow, white, or red, by impregnating the carbons with suitable chemicals; yellow is ordinarily preferred, obtained by mixing salt (sodium chloride) in the carbons. Since at the temperature of the arc all chemicals undergo decomposition, chlorine will be liberated; in order to prevent the escape of this highly poisonous and corrosive gas, ammonium carbonate is also included in the mixture for the carbons, thereby ammonium chloride (sal ammoniac) and sodium carbonate are formed and harmlessly deposited as white powders, along with the carbon dust, on the inside of the globe. Though suffering the handicap of required daily trimming, it is probable this form of lamp, giving the most powerful artificial light yet produced, will receive extensive adoption for out-of-door uses.

Very small arc lamps have not given entire satisfaction; the mechanism must accomplish identical results with the large lamps, yet is comprised in smaller space; the illumination is not proportionate to the energy expended, for a given amount of energy expended in a number of small lamps does not equal in illumination that which would be obtained from a smaller number of large lamps. This is a peculiarity not of arc lamps alone, but is a matter of regular experience with incandescent and gas lamps. For street lighting the 500 watt arc lamps are generally adopted, but for stores, especially when the lamps are connected in multiple, 350 to 400 watt sizes are common, a little sacrifice in economy being permissible in consequence of the better distribution obtained from the relatively large number.

The real candle power of the arc light is a matter of difficult determination; there are no standards of the same quality of light with which to compare it. Twenty years ago the 45-volt, 10-ampere open lamps were guessed to emit about 2,000 candle power; more modern measurements assign the actual figures as more nearly 500. The 80-volt, 6½-ampere inclosed arc gives about the same amount, but for street lighting, especially, the latter gives the more satisfactory results, for the greater prevalence of the horizontal rays gives a better average illumination; directly under an open lamp the rays are very intense, but rapidly diminish as distance from the arc increases. Unless the flaming lamp can be made in small sizes, it would seem to be limited in use to public squares and for exhibitional purposes.

Standard sizes of hard carbons for open lamps are 12 inches long, 7/16 inch and ½ inch in diameter, the softer grade for inclosed lamps 8 inches long, ⅜ inch, 7/16 inch, ½ inch, and even ⅝ inch in diameter. The smaller diameters give the better light, but, naturally, do not last as long as the larger ones.

The fifth article will consider the topic of "Constant Potential Generators" for direct currents.

(To the continued.)

# EDDY CURRENT BRAKE FOR RATING GASOLINE MOTORS.

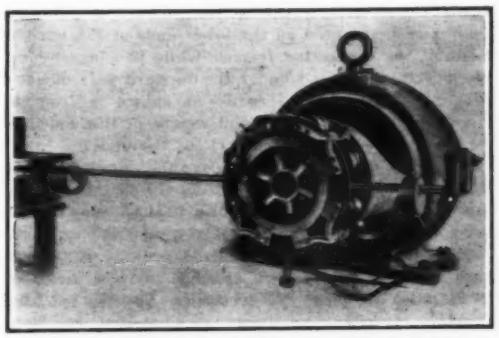
## BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

A NEW and novel type of electromagnetic brake has been designed for determining the rating of gasoline, electric, or other motors with accuracy and ease by Messrs. Morris & Lister, engineers, of Coventry, England. The apparatus is of simple design, comprising two copper disks mounted on a bush which is keyed to the spindle or crankshaft of the motor to be tested. Between these disks is an aluminium casting, which acts as a floating central hub, carrying the magnetizing coils, the external yoke rings, and the graduated and balance levers. The coils are excited by a direct-current supply, and produce a powerful multipolar magnetic field in the gap in which the disks revolve. Eddy or Foucault currents are generated, and the output of the motor is thus expended in heating the copper disks. The potential of the induced currents, and consequently the brake horse-power absorbed, depends upon the intensity of the magnetic field, and this is readily controlled by means of a rheostat in the exciting circuit. The forces resulting from the inaction between the magnetic field and the induced currents in the disks tend to drag the floating system or aluminium hub round. The energy, however, is opposed by a gravitational force due to the weighted lever. When these two forces become equal, the lever floats between its stops. The torque or turning moment exerted by the motor in pounds-foot is then equal to the product of the weight in pounds into its radius of action in feet. The output of the motor is given by

$$\text{B. H. P.} = \frac{2\pi \times \text{radius in feet} \times \text{weight in pounds} \times \text{R.P.M.}}{33{,}000}$$

This ingenious brake possesses many advantages over the ordinary types of absorption dynamometers. In the first place, it can be more easily and rapidly adapted to any type or size of motor, while owing to the brake being carried by the motor spindle no separate frame is necessary. It is very sensitive in working, the load is uniform, while a fine degree of accuracy is obtained, since there are no sources of appreciable error. The balance can be secured in a few moments, and the lever kept floating by means of the rheostatic control. Wear is reduced to a minimum, while all the difficulties attending the utilization of burnt blocks, bands, ropes, and the necessity of water for cooling as in the ordinary brake testing system are obviated, while furthermore the formula for calculating the horse-power does not vary with the conditions of working.

The eddy current brake, however, is not advocated for time tests except under special conditions, since these can be more economically undertaken by either of the various regenerative methods available. The



EDDY CURRENT BRAKE FOR RATING GASOLINE MOTORS.

great advantage of the eddy current brake is the rapidity and accuracy with which efficiency of a motor can be determined before and after a prolonged test. A complete set of six or eight observations of efficiency between no load and 50 per cent overload can be obtained in as many minutes. The brakes are consequently rated to absorb a given power for fifteen minutes without undue heating, but they may be overloaded up to 100 per cent for two minutes, and will absorb smaller powers for longer periods. The speeds of the brakes range from 1,500 revolutions per minute for a motor of 2 horse-power to 750 revolutions for a 30-horse-power motor. These speeds, however, may within certain limits be increased by 50 per cent, but more satisfactory results can be obtained by employing a smaller type of brake, since the best results are insured by working the brake at its designed speed. If necessary the brake may be fitted with suspension links, by means of which the weight of a brake can be carried from an overhead fixing, thus relieving the motor bearing of any stresses. But under normal conditions, however, such suspension is not requisite, as the weight due to the brake is considerably less than the pull due to a belt drive.

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In connection with the Austrian governmental establishment for the preparation of uranium products, there has been built in Joachimsthal, Bohemia, a laboratory for working up radio-active substances found in the tailings and by-products of the uranium minerals. There will also be erected a bathing establishment, where the radio-active mine water will be used for healing purposes.

## CATHODE RAYS AND THE AURORA.*

By C. CHREE.

SEVERAL physicists have advanced the theory that cathode rays play a part in aurora. Prof. Birkeland has described a number of phenomena produced by cathode rays in the neighborhood of a magnetized sphere, which resemble various types of aurora. He supposed the sun to be a primary source for cathode rays, which might set up secondary rays in the earth's atmosphere. Mr. C. Stormer has carried out elaborate calculations as to the possible ways in which electrified particles coming from a great distance can approach a magnetized "earth"; his results tend to limit the approaching particles to the space near the magnetic poles. Prof. S. Arrhenius has supposed electrified particles to be driven from the sun by the repulsion of light and to reach the earth's atmosphere in about two days, originating aurora and magnetic storms.

In a recent article on this subject, M. Villard refers to Arrhenius's theory, but seems somewhat skeptical as to the supposed solar origin of the electrified particles. His own views appear to be a combination of theory and observation as to what happens to ions or electrified bodies of any kind moving in a magnetic field. In a uniform field the ion, when traveling with uniform velocity, describes a regular helix on a cylinder the axis of which is parallel to the lines of magnetic force. The radius of the cylinder varies directly as the component of the velocity perpendicular to the lines of magnetic force, and inversely as the intensity of the field. Suppose, however, that the magnetic field is not uniform, but increases in intensity in the direction in which the ion travels; then, as has been shown by Poincaré, the path forms a curve with diminishing spirals on a cone, and before actually reaching the summit of the cone the particle ceases to advance, and retires, the spirals gradually opening out. If, for instance, the field is that due to two elongated parallel poles, then if the particle gets under way between the poles, traveling obliquely to

* Abstracted from Nature.

the lines of force, there is a regular game of battledore and shuttlecock; the particle zigzagging to and fro slantwise, reversing its direction whenever it gets within a certain distance of either pole.

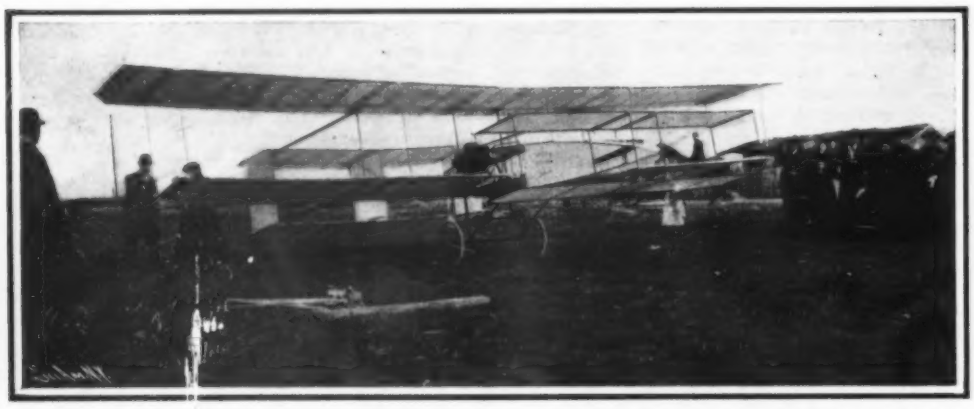
M. Villard supposes ions to get in motion somewhere in the earth's atmosphere. As to exactly how this comes about he is not prepared to dogmatize. He is inclined to think that cirrus clouds—which he believes to consist of ice particles negatively electrified—under the influence of ultra-violet light, or less probably under a solar bombardment such as Arrhenius postulates, are probable sources. He also thinks that not improbably a part is played by cosmical dust encountered in the earth's movement through space. Ions starting, say, from a cirrus cloud, and moving obliquely to the lines of magnetic force in the earth's atmosphere, will travel each in a spiral, the whole together forming a sort of luminous spindle, which on getting within a certain distance of, say, the south magnetic pole, turns as if reflected, makes for the north pole, suffers a second reflection there, and so on. The movement may be supposed to be set up by ultra-violet light from the sun falling on cirrus. The first band or two will thus be in the still illuminated hemisphere, and so invisible; succeeding bands will be overhead in the unlighted hemisphere, and will be visible. Passing further to the east, the energy will be gradually dissipated and the aurora cease to be visible, thus explaining why the late evening, and not the morning, is normally the time of most brilliant aurora. To fit the theory, the charge carried by the particles must be negative. If positive, the motion would be from the east, and the principal aurora would be in the early morning. M. Villard supports his theory by photographs of radiations from a magnetic pole. He obtains results suggestive of the appearance of aurora displays which are very interesting.

Other phenomena analogous to the "dancing" of auroral rays are easily produced by advancing or withdrawing a bar magnet. M. Villard seems to regard magnetic disturbances rather as agents causing auroral phenomena than the converse, but this theory seems still in a somewhat uncrystallized state. Those actually familiar with auroral phenomena will think of a number of points requiring explanation to which M. Villard does not refer; but his researches, like those of Prof. Birkeland, are at all events highly interesting and suggestive.

# RECORD FLIGHT OF THE FARMAN AEROPLANE.

## THE BEST EUROPEAN PERFORMANCE.

THE large aeroplane shown in the accompanying illustration is of the double-surface, following-plane type. It is quite similar in construction to the aeroplane of the sculptor Delagrange, which we illustrated in the SCIENTIFIC AMERICAN of March 30, 1907. The latter aeroplane, last spring, made several short flights quite successfully, and showed that it had good stability. M. Farman has constructed his aeroplane along the same lines, but has given it a somewhat larger surface. His machine has a supporting surface of 697.5 square feet, as against 645.84 square feet of the Delagrange aeroplane. The two main aeroplanes of the Farman machine are 33.45 feet long by 6.56 feet wide, and placed at a distance of 4.92 feet apart. The rear pair of planes, which are placed about 15 feet back of the forward pair, are 19.68 feet long by 6.56 feet wide. A double horizontal rudder consisting of two small superposed aeroplanes is rigged in front of the forward pair of planes, and is arranged so as to be operated by the pilot from his seat in the rear of these planes. The 50-horse-power, 8-cylinder, V motor is mounted between the forward planes at their center, and is arranged to drive a single propeller which is keyed to its crankshaft. These planes consist of cloth tightly stretched in a slight curve from front to back over the ribs, which extend from the front to the rear wood strips forming the frame, and which project out a foot or more beyond the rear strip. These long transverse strips, or poles, are flexible and yielding. The two forward planes are connected together by sixteen vertical posts, while two rectangular vertical frames, each having three upright brace posts to strengthen them, extend backward a distance of about 15 feet from the forward planes to the rear planes. The uppermost of the two rear planes is placed in practically the same horizontal plane with the uppermost forward plane, but the lower rear plane tilts upward at a slight angle from its forward edge to its rear edge. Thus, the two rear planes, while about 5 feet apart at their front edges, are only about 4 feet apart at their rear edges. There are three vertical cloth-covered frames between the two rear planes, and located one at each end of these planes and one at their center. The two end vertical planes project back beyond the horizontal planes a distance of 1½ or 2 feet, while the center vertical plane only extends back about two-thirds of the width of the horizontal planes. There are two small, rubber-tired wheels at the forward edge of the rear planes, mounted on the lower ends of the upright posts of the connecting frames, while two larger bicycle wheels are rigged under the forward pair of aeroplanes. The horizontal rudder is shown in front of the forward planes. The total weight of this machine is given as 500 kilogrammes (1,102.3 pounds).



FRONT VIEW OF AEROPLANE, SHOWING HORIZONTAL RUDDER, ENGINE, AND PROPELLER ON REAR END OF ENGINE CRANKSHAFT.

In a very successful flight above the parade grounds at Issy-les-Molineaux on the 26th ultimo, M. Farman covered a distance of 771 meters (2,529.52 feet) in 53 seconds, or at an average speed of 32.54 miles an hour; while earlier in the day he made a flight of 363 meters (1,190.94 feet) in 30 seconds, or at a speed of 27.06 miles an hour. No particulars have as yet been received regarding the amount of wind that was blowing, and whether the flight was made with or against the wind. Presumably the flight would be made against the wind if there were any, and if this were the case, the new aeroplane has shown much more speed with a given horse-power than any of its predecessors that have flown. Supposing the motor to have developed its full power, the machine lifted from 22 to 25 pounds to the horse-power. The probabilities are, however, that a greater weight per horse-power expended was lifted. Each square foot of supporting surface carried a weight of about 1¾ pounds, from which it can be seen that the machine was not heavily loaded, as most of the recent French aeroplanes have carried from 2 to 2½ pounds per square foot. In view of the large supporting surface, the speed obtained is all the more remarkable. The machine does not appear to have been provided with vertical rudders, and as a consequence only straight-line flight was attempted. This long flight of nearly half a mile was the last of a considerable number of flights made during different days in the latter part of October. In all these flights the machine alighted successfully without damage, which is another point in its favor. In all probability, after vertical rudders have been fitted, we shall hear more from this particular aeroplane, or from others of a similar type.

## CALCIUM, ITS PROPERTIES AND POSSIBILITIES.*

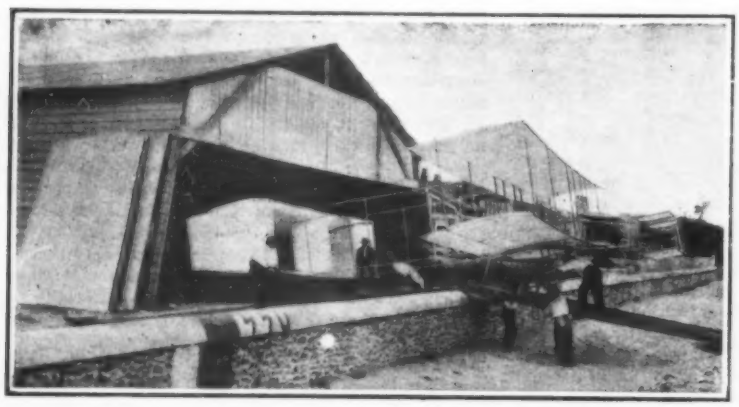
CALCIUM is a silvery white metal readily oxidized in moist air. It is very light (sp. gr. 1.52), fairly malleable, has a high specific heat, and is a good conductor of electricity. It is about as hard as aluminium, but at 400 deg. C. becomes as soft as lead. It is volatile, and can be sublimed *in vacuo* between 700 deg. C. and 800 deg. C., and melts at the latter temperature. It is a very powerful reducing agent.

The chief effects of alloying calcium with other metals are to produce brittleness, crystallization, and hardness; to promote oxidation and disintegration on exposure to air; to confer the power of decomposing water and in other ways increasing the chemical activity.

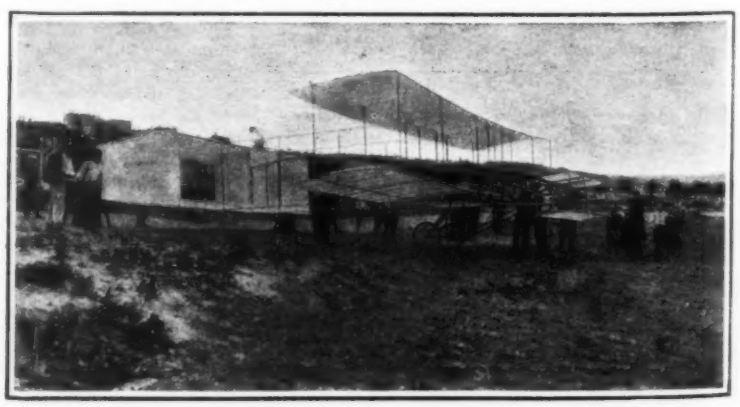
The author's experiments confirm Roberts-Austen's observation that the presence of small amounts of metals of high atomic volume will cause deterioration of the physical properties of metals of low atomic volume. The atomic volume of calcium is high (25.4), and the effect of small amounts on other metals is decidedly prejudicial, provided that the metals in question are pure. In the course of the work the following observations were made: When an alloy is made of calcium and some metal which possesses a chemical property in common with it, an increased activity in the manifestation of that property is noticed in the alloy. This increase appears to be greater than would be obtained by the simple admixture of a more active metal, the presence of calcium usually increasing the activity of the other metal. In some cases the alloy is more active than either of its constituents.

Further, the chemical properties of calcium appear to be more pronounced in an alloy with a metal hav-

* Abstract of a paper read by Arthur E. Pratt, B.Sc., before the British Association at Leicester.



THE AEROPLANE LEAVING ITS SHED.



THE AEROPLANE JUST BEFORE THE START.

FARMAN'S AEROPLANE WHICH RECENTLY BROKE ALL RECORDS IN FRANCE.

ing an atomic value closely approaching that of calcium than they are in an alloy of the same percentage with a metal having a much lower atomic value. The two metals in question should be about equally active when unalloyed in the particular property with respect to which they are to be compared. It is probable that both these principles are general, and not confined to calcium, although more extended research on these lines would be desirable.

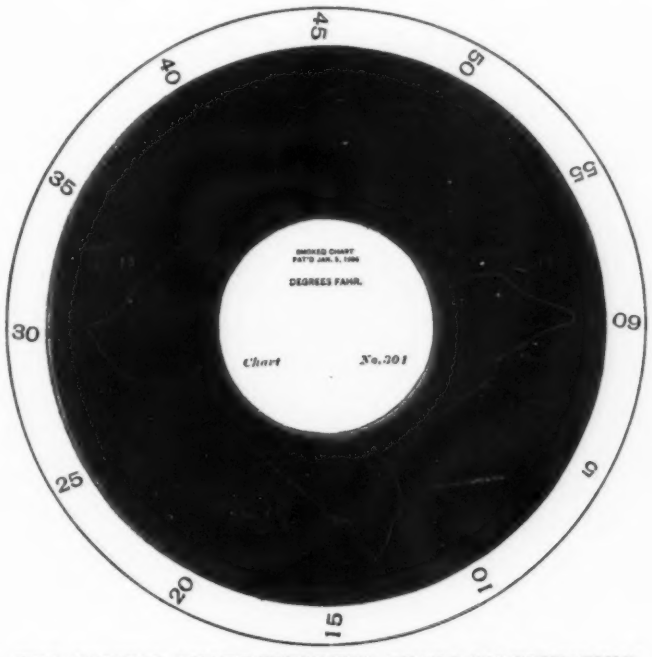
The most promising applications of calcium are as a reducing agent and for the refining of metals. In the latter case it acts in three distinct ways: (1) By reducing oxides and sulphides; (2) by eliminating dissolved gases; (3) by forming compounds with certain impurities, thus rendering them less deleterious. All three modes of action are strikingly shown in the case of copper. A suitable addition of calcium will remedy "dry" or "sulphury" copper, give a sound casting, and give a soft and tough ingot with prohibitive proportions of bismuth or antimony, besides restoring ordinary overpoled copper to tough pitch. If excess of calcium is present, however, it induces brittleness on its own account. With one or two doubtful exceptions, no alloy of calcium has shown any promise of commercial utility so far as physical properties are concerned, its only likely application in this direction being its hardening property.

# ELECTRIC METAL-TESTING PYROMETER.

## A NOVEL LABORATORY APPLIANCE.

### BY WILLIAM H. BRISTOL.

THE apparatus herewith illustrated has been designed for the purpose of determining by the use of a small electric furnace, an automatic electric pyrometer, and a semi-smoked chart card, the degree of temperature at which the heating or cooling of steel is retarded, or technically known as the recalescent points above which steel will harden. We are informed that all of these devices are covered by patent protection. The whole apparatus is so small and compact that it can be placed on an office desk, the electric current being supplied from an ordinary lighting circuit.

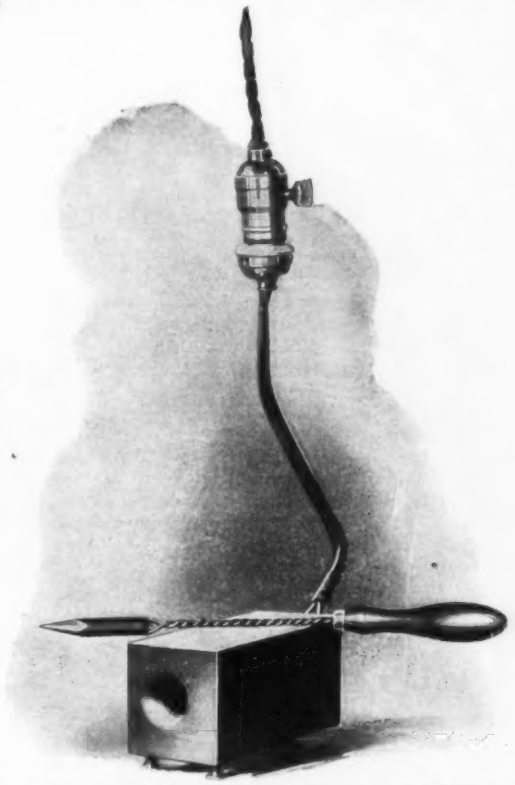



THE BRISTOL SMOKE-SURFACED CHART ILLUSTRATING FOUR DIFFERENT TESTS.

One of the illustrations represents the electric furnace itself in a horizontal position, in the center of which is an opening for the insertion of a soldering iron. The wires from the furnace are connected to a lamp socket. Within the center of the resistance or heating coils is a lining of fused quartz which, after the current is turned on suddenly, will heat up rapidly without cracking or becoming in the least damaged. Even while the quartz lining is heated to a bright red, if a cold piece of steel is introduced it will not injure the quartz lining in the least. The quartz acts as a perfect insulator between the steel and the heating coils. The soldering furnace is wound in a special way to allow for the maintaining of a uniform maximum temperature that will not be too high to oxidize the soldering iron. In this case, no rheostat is required to vary the amount of current.

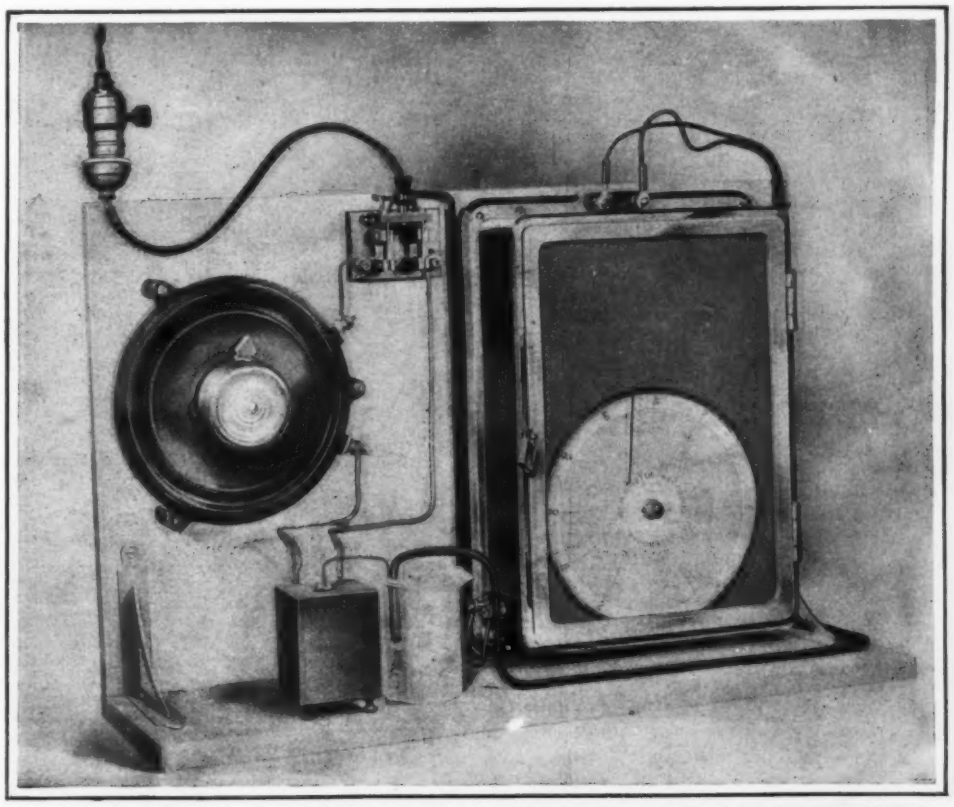
In the experimental apparatus as shown in the larger illustration, the current is led off from the lamp socket to a switch, and passes from this to a rheostat, thence to the furnace interior coils and back to the switch. The furnace stands in an upright position on the left. After the current is turned on, the interior furnace quartz lining is brought up to a bright red heat very quickly, then its temperature may be adjusted to any desired degree by simply operating the rheostat handle one way or the other. On the right of the illustration, inclosed in a case, will be observed the automatic electrical recording pyrometer, which has previously been described in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 1610, November 10, 1906. Between this instrument and the furnace is placed a jar filled with ice water in order to maintain a constant temperature of 32 deg. F. The piece of steel to be tested is drilled through its center with a small hole in which the pyrometer electrode or couple is inserted, and consists of a platinum, platinum-rhodium thermo-electric couple. Each of the fine wires is insulated, except at the lower terminals, which are bare and welded together. The twin insulated wires then pass upward and over to and into the beaker of ice water, where a constant temperature of 32 deg. is maintained, and are connected to the main wires leading to the recording apparatus on the right. The pyrometer needle will be observed on the left in the clear window portion of the case. The needle moves to the left or right in front of the revolving semi-transparent smoked chart operated by a clock movement in the rear, making one revolution in an hour.

A pair of shunt wires lead down from the main switch to terminals at the bottom of the case, which connect with an electro-magnet that automatically operates an armature vibrating arm behind the paper chart once every half second. This brings the smoked surface of the chart against the end of the pyrometer needle without friction, and removes a portion of the coating, leaving a white dot. The record is thus composed of a series of fine white dotted lines and is perfectly accurate.



THE BRISTOL QUARTZ-LINED ELECTRIC FURNACE FOR SOLDERING IRONS AND HEATING OF SMALL ARTICLES.

The illustration of the chart describes the record



THE BRISTOL LABORATORY ELECTRIC FURNACE AND ELECTRIC PYROMETER.

made on different specimens of steel and iron. To obtain a record of the recalescent points of a specimen lot of steel a small sample is selected of cylindrical form about 7/16 inch in diameter and about 1¼ inches long. A hole ⅛ inch in diameter and ¾ inch deep is drilled into the end of the sample.

After the electric furnace has been heated up by turning on the current, this piece of steel is inserted into the top furnace and the tip of the thermo-couple is introduced into the hole of the sample. As the steel is gradually heated up by the furnace the rising temperature inside it will be recorded on the chart. After the temperature has been raised as far as desired, the piece of steel may be withdrawn from the furnace without disturbing the couple, and as the steel cools its falling temperature will also be recorded on the chart.

The records of these rising and falling temperatures will be shown as curves on the charts on which the recalescent points will be easily discovered, as will be noticed in the angular form of the curve. The chart shows four of these records made with four different samples. Sample No. 2 on the chart was malleable iron and its heating and cooling curves show no points where the rise or fall of temperature was retarded. Sample No. 7 on the other hand shows two of these points, one going up and one going down. Sample No. 7 was 1.25 per cent carbon steel (Jessup tool steel) and was treated in exactly the same manner as sample No. 2. The record for No. 7 shows two points of retardation, one for heating at about 1,300 deg. F., and the other one for cooling at about 1,240 deg. F. This shows that to harden this lot of steel a temperature higher than 1,300 deg. F. should be used. Sample No. 19 was a low-carbon steel having different recalescent points, from the Bethlehem Steel Company; carbon content .2 per cent. Sample No. 18 was cast iron and shows a point of retardation for cooling only.

From the curves and recalescent points shown on the chart, it is evident that the temperature which would be right to harden one kind of steel would not be the right one to produce good results with another kind of steel. By making tests like those described above, the manufacturer can find out what temperature is the best one for him to use in hardening each particular lot of steel. The old-fashioned idea that steel could be hardened by guesswork is fast giving way to the realization that a piece of steel may become either worthless or precious according to what heat treatment it receives.

It will be observed by reference to the chart record that the complete test of each sample was finished in less than fifteen minutes after starting with a cold piece of steel, and that the critical points of the heating and cooling curves were recorded within seven minutes of each other. It has been found by experience that the curves obtained for these small samples with this outfit have the same characteristics and give the same results as those obtained by using large masses of metal which would require considerable time for heating and cooling. The figures on the periphery of the chart represent minutes.

In one of the largest western steel works the system has been adopted of having a pyrometer indicator placed near the furnace for the operator to observe and a recording instrument in the same circuit, located at a distance in the superintendent's office, which has been of much use in enabling the workmen to produce a uniform quality of steel.

# STEAM VERSUS ELECTRIC LOCOMOTIVES.

## THE STEAM LOCOMOTIVE CAPABLE OF STILL GREATER EFFICIENCY.

AT a recent meeting of the New York Railroad Club, Mr. Max Toltz, general manager of the Manistee & Grand Rapids Railroad Company, read a most interesting paper, in which he took issue with Lewis B. Stilwell and Henry St. Clair Putnam in an estimate they gave before the American Institute of Electrical Engineers last January, that "if all the railroads of the United States were to-day operated by electricity the aggregate cost of operation, which in 1905 amounted in round numbers to $1,400,000,000, would be reduced by about $250,000,000."

In undertaking to controvert this, Mr. Toltz went into details pertaining to steam locomotives—namely: repairs and renewals of locomotives, engine and roundhouse men, fuel for locomotives, and water supply for locomotives. In doing so he discussed at much length the value of superheaters and strongly urged their use. He sought to show that the steam locomotive properly improved is far more economical than the electric locomotive, even taking it for granted that a kilowatt hour of electrical power could be furnished at the low figure of 6 cents at the bus bars and at 8 cents effective for traction, as named by Stilwell and Putnam, who had further stated that a horse-power effective for a traction will cost 6 cents, of which 3.5 cents is for fuel when coal of 14,000 B.T.U. a pound costs $3 a ton of 2,240 pounds, and 2.5 cents is for other power-house supplies, power-house labor, and maintenance of power-house equipment.

In analyzing the statements, Mr. Toltz computed the horse-power of 47,000 locomotives reported in service by the Interstate Commerce Commission in 1904 at 16,625,000,000, and said: "The average freight locomotive is actually on the road not more than six hours in each 24-hour period, and the same figure is approximately correct for the passenger locomotives. Assuming that each locomotive will develop during the six hours' work at every time 250 horse-power (a very low estimate), the total number of horse-power hours per annum will then be nearly 26,000,000,000. In the reports of the Interstate Commerce Commission, 1905, it is also stated that nearly $156,500,000 were expended on fuel for locomotives. Dividing this item by the total horse-power hours per annum would give a cost of six cents for fuel per horse-power hour, compared with the estimated cost of fuel of 3.5 cents as above mentioned when assuming the railroads are operated electrically. This former figure is practically correct, because we know that on the average a steam locomotive will use 28 pounds of steam per horse-power hour. The average coal used in a locomotive boiler will evaporate about 6 pounds of water, which would necessitate 4½ pounds of coal per horse-power hour; at $3 per ton of 2,240 pounds will amount to six cents per horse-power hour. This, indeed, shows that more fuel per horse-power hour is being consumed in locomotives than in modern stationary plants which furnish power for electrical operation."

Mr. Toltz questioned the fairness of a comparison of an up-to-date power plant with the average locomotive. About 60 per cent of the locomotives now in use were built, he says, over fifteen years ago, are of the smaller type and cannot be worked as economically as the latest type, such as the Prairie, the four-cylinder balanced compound, and the Mallet articulated compound with wide fireboxes. The reasoning for comparison should therefore, he urged, be made upon the basis of the latest type of locomotives, and therefore he referred to the locomotive tests made during the World's Fair at St. Louis, which have established the fact that the coal consumption per horse-power hour was considerably less than 2½ pounds. Yet to properly dissect the economy in the locomotives, he called attention to the fact that each locomotive has one most economical speed limit, or, in other words, that on a given grade at a certain speed with a defined maximum load the locomotive will turn out the most work at the lowest cost.

In his conclusions, Mr. Toltz expressed the opinion that with the use of superheaters, smoke consumers, and automatic stokers, the work of engine crews will be decreased in many respects. Less coal will be handled by the fireman, and in connection with perfect lubrication, the work of the steam in the cylinders will be greatly improved. There should be no blown-out cylinder heads due to accumulation of water. Better and quicker starting of the train will be attained. Failures of non-steaming will be avoided by heating the feed water. There will be fewer leaky flues and fireboxes. Roundhouse labor on the boiler will be minimized, though the use of some coals, such as Illinois and Iowa, will require more attention to the cleaning of the smoke flue superheater. Fireboxes and flues will last longer; and last, but not least, the curse of uncleanliness, due to locomotive smoke, will be abated under conditions of perfect combustion in the firebox.

Estimating that the three improvements or devices can be added at a cost of less than $4,000 a locomotive, Mr. Toltz figured that the total expenditure for 47,000 locomotives would be $188,000,000, and this would be repaid within 22 months and 12.5 months, respectively, according to the following propositions, the percentages in the first being taken from the 1904 report of the Interstate Commission:

NO. 1.

| | |
|---|---|
| 30 per cent of $130,500,000 for engine and roundhouse men (2) | $39,150,000 |
| 39.2 per cent of $156,500,000 for locomotive fuel (3) | 61,348,000 |
| 30 per cent of $9,150,000 for water supply (4) | 2,745,000 |
| Total saving per year | $103,243,000 |

In this no account has been made for reduction of repairs and renewals, item (1).

Assuming that all existing locomotives are of the latest types, using instead of 4¼ pounds, only 2.6 pounds of coal per drawbar horse-power, as stated above, and are equipped with the saving devices, the problem will resolve itself into the following:

NO. 2.

| | |
|---|---|
| 42.2 per cent less coal for modern equipment | $66,040,000 |
| 39.2 per cent of $90,460,000 (item 3), about ($90,460,000, $66,040,000, $156,500,000, total item 3.) | 35,460,000 |
| 30 per cent of $115,000,000 (item 1) | ..... |
| 30 per cent of $130,500,000 (item 2) | 73,650,000 |
| 30 per cent of $9,150,000 (item 4) | 2,745,000 |
| Total saving per year | $177,895,000 |

The speaker declared that Stilwell and Putnam's statement relative to the reduction of the four items referred to when all roads are electrically operated, assumed a saving of:

70 per cent in item 1, repairs and renewals of locomotives;

50 per cent in item 2, engine and roundhouse men;

50 per cent in item 3, fuel for locomotives, and

100 per cent in item 4, water supply for locomotives.

Accordingly, the savings would be as follows:

| | |
|---|---|
| Item 1— 70 per cent of $115,000,000 | $80,500,000 |
| Item 2— 50 per cent of $130,500,000 | 65,250,000 |
| Item 3— 50 per cent of $156,500,000 | 78,250,000 |
| Item 4—100 per cent of $9,148,000 | 9,148,000 |
| A total of | $233,148,000 |

In closing, Mr. Toltz said: "The amount of capital which must be expended to obtain these doubtful results can hardly be imagined. A conservative estimate would be several billions of dollars. Although the estimated savings by an electrical equipment might warrant such an immense expenditure, the improvement of the steam locomotive offers like inducements. It has been the boast of the advocates of railroad electrification that with an electric locomotive double the trailing tonnage can be hauled at double the speed of the present steam locomotive. The writer begs to state that the steam locomotive of to-day (and not the most powerful one yet built) takes 800 tons singly and 1,600 tons doubly over a mountain grade of 2.2 per cent with a speed of 10 miles per hour.

"The electric locomotive, either in single or multiple units, has its place in big terminals and in tunnels, but it cannot in its present development replace the steam locomotive for trunk-line service. The writer has investigated some of the greatest water-powers in the Rockies and in the Cascades, and he ventures to say that none of them can deliver electrical power per drawbar horse-power per hour for less than five cents. Another feature over which most enthusiasts of electrification stumble is the high power factor which is assumed. If electrically operated to-day, the power factor would not exceed 48 per cent on three typical American railroads: the Great Northern, Northern Pacific, and Canadian Pacific. These are facts, as Daniel Webster once said, which can invariably be proved, and it will therefore be a little time yet before our old standby, the steam locomotive, will be relegated to the scrap heap, if our fraternity will assist in making this old friend of ours what it should be."

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**Turpentine and rosin** were produced in 1905 to a total value of $23,937,024. Almost three-fourths of the product was reported for two States—Florida, with a value of $9,901,905, or 41.4 per cent of the total, and Georgia, with $7,705,643, or 32.2 per cent of the total. Alabama and Mississippi, with $2,434,365 and $2,365,720, respectively, were next in importance. North Carolina, South Carolina, and Louisiana were the only other States reported for this industry. The quantity of crude turpentine distilled was 5,294,139 barrels of 280 pounds each. The production of spirits of turpentine amounted to 30,687,051 gallons, valued at $15,170,499, and that of rosin to 3,508,347 barrels, valued at $8,725,619. Of the total production, 14,792,238 gallons, or 48.2 per cent, of the turpentine, and 1,198,072 barrels, or 34.1 per cent, of the rosin were consumed in the United States. The exports amounted to 15,894,813 gallons of turpentine, valued at $8,902,101, and 2,310,275 barrels of rosin, valued at $7,069,084.

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**Señor J. Comas Solá** who has been closely studying the third satellite of Jupiter, has made an interesting report. The satellite, like the planet Mars, has snow-caps on its poles, that on the northern pole being the larger. As on Mars, the northern cap of the satellite is always bordered by a dark area, which appears darker toward the cap. The dark areas are difficult to observe, but appear to be very variable in a short time.

# USE OF GAS FROM A HYGIENIC STANDPOINT.*

## WHAT GAS MEANS IN A BUILDING.

BY PROF. VIVIAN B. LEWES.

Concluded from Supplement No. 1661, page 275.

DURING the past twenty years coal gas has been making wonderful headway as a fuel and the gas engine in many a crowded town helps to decrease the smoke curse under which our big towns labor. Indeed, the convenience and cleanliness of the gas stove is such an important factor in domestic life that the use of gas for fuel purposes now is as valuable in the prosperity of the gas undertaking as is its use for illuminating purposes. The only point which militates against it in the public mind is the assumption that it is much more expensive than solid fuel, but if we take into consideration all the conditions existing in our ordinary stoves and those to be found in the newer forms of gas stoves, experiment will soon show that this is not the case, and that the ratio of cost between the two largely depends upon the efficiency of the stoves used, and the way in which the heat is imparted to the air of the room.

Gas stoves may be classified in three groups:

1. Flueless stoves, in which the products of combustion, either before or after condensation of water vapor, are discharged into the air.

2. Radiant heat stoves, in which refractory bodies are heated to incandescence, and the heat is radiated into the room, the hot products and some unburned gases escaping by a flue.

3. Stoves of the same kind as 2, but in which by means of air chambers, regeneration, or passing the products through a length of metal pipe, most of the heat is withdrawn from the products of combustion before discharging into the flue.

In the first class of stoves all the heat of the burning gas passes into the air of the room and practically the whole of the heating is done by hot air and convection.

In the second class of stoves the heat is mostly discharged into the room by radiation, while in the third class both radiation and air-heating come into play.

There is not the slightest doubt from a hygienic point of view that heating by radiation is infinitely preferable to effecting the heating by warming the air, and this is one of the factors that make the English open fire so superior in comfort to the closed stoves and other air-heating devices so popular on the Continent.

A good gas stove, like the open fire, should not depend too much for its heating effect upon discharging warm air into a room, but should distribute a considerable proportion of its heat by radiation, and so raise the temperature of the floor and furniture in the lower parts of the room.

Radiant heat does not directly raise the temperature of the air, but is radiated to the floor, walls, and furniture of the room, which again slowly part with their heat to the air in contact with them and to the inhabitants, so that the walls and other solid bodies in the room are at a higher temperature than the air.

Apart from its being much more healthy to breathe cool than hot air, there is another important point to consider. The normal temperature of the body is 98 deg. F., and this temperature is maintained by the slow combustion processes going on in the body. By the laws of radiation a heated body parts with its heat more or less rapidly according to the temperature of the surrounding bodies, so that if a person be sitting in a room filled with warm air, but near a wall colder than the air, his body will rapidly part with the heat by radiation to the wall and a sensation of chill is the result. But with the open fire this is never the case, as the radiant heat from the fire heats the walls of the room to a temperature higher than that of the air. When, however, a room is heated by means of warm air, the walls not being heated in the same proportion, though the air may feel warm, the walls will remain cold; so that the heat of the body would pass by radiation to the walls and give rise to a chill.

Whatever views may be held on the subject, I feel very strongly that the idea that some forms of stove can be used without being attached to a proper flue is not only dangerous to health, but also militates against the use of gas as a fuel, by encouraging the idea that gas stoves are unpleasant and unhealthy as sources of heat. It cannot be insisted on too strongly that a gas fire whether used for heating or cooking must be connected with a flue, as the products of combustion are just as deleterious, if not so dirty, as those given off by the combustion of solid fuel.

I have on many occasions protested against the sale of flueless stoves, but freely admit that in spite of protests and preachings they continue to flourish and have, indeed, multiplied in number more than any other form of gas heater. Some of these stoves are small stoves of the ordinary types, while others, known as condensing stoves, are so arranged as to condense the water formed by the combustion of the gas, and the makers gravely assure the public that this removes all deleterious products. The popular idea of a deleterious product is something that has an offensive taste or smell, or that in a very short space of time seriously affects the health, and if this view be accepted, then the makers of these condensing stoves have a modicum of truth in their statement, as the condensing water removes some of the products of the combustion of the sulphur in the gas, and where the gas used is exceptionally foul, this prevents a certain amount of discomfort. The ventilation of our rooms, however, is never too perfect during the periods that necessitate the use of the gas stove and the fact cannot be got away from, that for each cubic foot of gas burned half a cubic foot of carbon dioxide is formed, none of which is taken up by the condensing water. The gas, moreover, is discharged near the floor of the room, and being fairly cooled before leaving the stove, mingles with the air in the lower portion of the room, instead of rising, as the products from an exposed flame do, straight to the ceiling space.

A long series of tests made with these various forms of stoves show, as might be expected, that with the flueless stove the whole of the heat finds its way into the room and it did not in the least matter whether the gas was burned in a flat flame or Bunsen burner near the floor level, or whether it was consumed in a regenerator or condensing stove of the most costly and complicated pattern. In all cases the result was the same, and if the consumer does not mind hot foul air and injury to his health, a few Bunsen burners low down in the room is the most effective form of stove that can be used; indeed, this method of heating is, I am sorry to say, employed in certain popular restaurants.

One of the commonest complaints against gas stoves is that they "dry the air" and this is entirely brought about by those forms of stove that heat the air, as by so doing they give it a greater capacity of taking moisture from the human body, and so produce a feeling of discomfort.

In the second class of stoves, which do the main part of their heating by radiant heat, and which from the hygienic standpoint are undoubtedly the best, it was found that only 35 per cent of heat was utilized in the room, the remainder passing up the chimney, while with those stoves fitted with air chambers, regenerators, and other devices, naturally considerably more heat could be utilized.

There is not the least doubt that from every point of view the best and most hygienic method of using gas for heating is the one which experiment has shown to be the least economical, and one of the most important problems in gas-stove manufacture is to find how far it is possible to convert the calories in the gas into heat radiations, and in attempting to do this considerable information can be gleaned from the theory of the incandescent mantle.

The most valuable and complete research on the mantle is that by M. Charles Fery, published at the close of 1902. The conclusion he arrives at is that a mantle of ceria gives no light because it has so great a power of heat radiation that it is impossible to raise its temperature sufficiently in a flame (the temperature of which is limited by the phenomena of dissociation) to endow it with the power of emitting light. When, however, the ceria is sufficiently attenuated by subdivision in a thoria mantle it can be raised to the required temperature and the light of the Auer mixture is the result.

In 1903 M. E. Sainte-Claire Deville published some experimental results on mantles which led him to support the theory enunciated by Fery, and in January, 1905, in a lecture given before the Junior Institution of Engineers and which was published *in extenso* in both the Journal of Gas Lighting and the Gas World, I gave the results of a series of experiments which entirely indorsed this view, and which, as they have been overlooked apparently in recent work on the subject, I will again repeat.

When mantles of thoria, ceria, and various mixtures of the two are made of exactly the same size and shape (which can be done by using a Buhlmann burning-off apparatus) and when these mantles are tested in a properly regulated Kern burner, so as to avoid the use of a chimney, all conditions being kept exactly the same for each, it is found that the flame extends only a millimeter or two beyond the mantle, and that the thoria and 99 per cent thoria with 1 per cent ceria are the only mantles that are heated to temperatures slightly higher than are found in the flame, 1 millimeter from the surface of the mantle. The temperatures of the mantle and flame, however, vary enormously with the character of the mantle, and the following table gives the mantle temperature and flame temperature taken 6 millimeters above the rim of the burner, a point at which the mantle is just free from disturbing elements, and where the maximum light is being emitted. There is also given a relative radiation value for the mantles obtained by a thermopile placed at a fixed distance from them, all measurements being taken with every possible precaution to insure accuracy. The thoria was not absolutely pure, containing 0.1 per cent ceria, so that the mantle gave 3.4 candles per cubic foot of gas consumed instead of 0.5, and this probably makes the radiation value higher and the mantle temperature lower than it would be for pure thoria.

TEMPERATURES AND CANDLE-POWERS OF VARIOUS MANTLES.

| | Composition. | | | |
|---|---|---|---|---|
| | Thoria....99.9% Ceria..... 0.1% | Thoria.... 99.0% Ceria..... 1.0% | Thoria.... 90.0% Ceria..... 10.0% | Ceria. |
| | Deg. F. | Deg. F. | Deg. F. | Deg. F. |
| Temperature of mantle 6 mm. above burner rim | 1,610 | 1,570 | 1,335 | 1,125 |
| Temperature of flame 1 mm. from mantle in same spot | 1,590 | 1,560 | 1,350 | 1,130 |
| Average temperature of mantle up to height of 52 mm. from burner | 1,408 | 1,411 | 1,209 | 1,020 |
| Average temperature of flame over same zone | 1,430 | 1,439 | 1,234 | 1,032 |
| Illuminating power; candles per cubic foot of gas | 3.4 | 20 | 3.3 | nil |
| Radiation value | 140 | 152 | 218 | 234 |

These experiments show clearly that thoria with its low specific heat and low radiating power for heat can be raised to the temperature of the flame, while ceria by its excessive heat radiation cools the flame and mantles.

As far as experiments have gone ceria appears to be the body having the greatest power of heat radiation, and in order to gain an idea of the proportion of the calorific value of the gas used up, I have made experiments from which it was possible to compare the heat escaping from the products of combustion with the heat radiated by the heated body.

Mantles of varying composition, but all identical in size and shape, were heated on a Kern burner, the consumption of which was kept constant at 4.6 cubic feet per hour. The gas used was South Metropolitan gas, having a calorific value, as determined in the Junker calorimeter, of 137.5 calories gross. A mica chimney 4 inches in length was fitted into the aperture at the bottom of the calorimeter, and the burner and mantle were so arranged that the tip of the mantle projected half an inch into the chimney, so that readings of the radiation could be taken without the disturbing influence of any surrounding media, while the products of combustion practically all passed up into the calorimeter. The radiating value was measured by a thermopile, placed with its face one foot from the center of the mantle, and the following values were obtained:

| | Calories, gross. | Radiation value. |
|---|---|---|
| Burner without mantle | 107.6 | 23.5 |
| Pure thoria mantle | 94.5 | 74 |
| Ordinary Welsbach mantle | 91.9 | 79 |
| Mantle with 10 per cent ceria | 80.3 | 100 |
| Pure ceria mantle | 71.1 | 139 |
| Pure alumina mantle | 91.3 | 81 |
| "Sunlight" mantle | 90.5 | 84 |

These results show that the pure ceria, which has the highest radiation value, translates 48.2 per cent of the calorific value of the gas into heat radiations, while with such bodies as alumina, which might be taken as representing very nearly that of the radiating power of the balls used generally in gas fires, 33.6 per cent is obtained, which corresponds fairly well with experiments made upon the best form of stove dependent for heating power on radiation only.

Experiments were then made with a fire ball taken from an ordinary stove: this was heated in an atmospheric burner flame at a distance of 18 inches from

* Lecture delivered before the British Institution of Gas Engineers at Dublin, Ireland.

the thermopile and the radiation being determined, the ball was dipped in a dilute solution of cerium nitrate, re-ignited, and on testing as before was found to give an increase in radiation of 12 per cent, an experiment which shows that it may be possible to improve at any rate to this extent the radiative power of the material heated in the gas stove, and I find that Mr. Edgar is making a radiating fuel on this principle.

Several interesting points were raised by Mr. Brearley's paper this afternoon, one of which was that luting the gas flue air-tight into the chimney space caused a lowering of radiant heat, and the cause of this is evident, as an enormous amount of cold air is sucked in from the room over the surface of the incandescent material, which is cooled down at the expense of the radiant heat. Not only may the radiation be increased some 2 or 3 per cent but gas fires of this class may be made as important engines of ventilation as the open fuel fire, by making the short gas fire chimney act like the gas injector of a Bunsen burner and draw in air from the room into the chimney well above the fire itself.

The great fault with most of the stoves on the market is the high gas consumption, many of them using from 30 to 50 cubic feet of gas per hour, and this, by unduly swelling the consumer's gas bill, creates a prejudice against the use of gas as a fuel, but there is an immense future for a good stove consuming 12 to 15 feet per hour, and advances are being made in this direction.

In constructing gas stoves care must be taken not to cool the products of combustion too far before they discharge into the flue, as if the temperature is reduced below the boiling point of water, although a slight increase in heat is obtained, water is condensed, and taking up the sulphur oxides formed from the carbon disulphide vapor in the gas forms a highly corrosive liquid, which rapidly eats away the metal work of the connecting flue to the chimney and corrodes the iron work of the back of the stove.

Gas cookers are daily becoming more firmly established and the early prejudices against them having been overcome by experience, their convenience and economic advantages are leading to their almost universal adoption, but where they are extensively used a ventilating shaft with a good updraught should be in connection with a hood a few feet above the stove, as there is one phase in the use of gas fuel which should never be overlooked and that is that if a cold substance, metal or non-metal, be placed in a flame, whether it be luminous or non-luminous, it will be observed that there is a clear space in which no combustion is taking place, formed round the cool surface, and that as the body gets heated this space gets less and less until, when the substance is at the same temperature as the flame itself, there is contact between the two. Moreover, when a luminous flame is employed in this experiment the space still exists between the cool body and the flame, but you also notice that the luminosity is decreased over a still larger area, although the flame exists.

This means that in immediate contact with the cold body the temperature is so reduced that the flame cannot continue burning, and so is extinguished over a small area; while over a still larger space the temperature is so reduced that it is not hot enough to bring about decomposition of the heavy hydrocarbons with liberation of carbon to the same extent as in the hotter portions of the flame. Inasmuch as when water is heated or boiled in an open vessel the temperature cannot rise above 100 deg. C., and as the temperature of an ordinary flame is over 1,600 deg. C., it is evident that the burning gas can never be in contact with the bottom of the vessel, or, in other words, the gas is put out before combustion is completed and the unburned gas and products of incomplete combustion find their way into the air and render it perfectly unfit for breathing.

Experiments made several years ago on the gases escaping while a vessel of water was being heated from the ordinary temperature up to the boiling point gave the figures in the following table:

COMPOSITION OF GAS IN FLAMES.

| | Bunsen flame | | Luminous flame | |
|---|---|---|---|---|
| | Inner | Outer | Inner | Outer |
| Nitrogen ..... | 75.75 | 79.17 | 77.52 | 69.41 |
| Water vapor..... | 13.47 | 14.29 | 11.80 | 19.24 |
| Carbon dioxide.... | 2.99 | 5.15 | 4.93 | 8.38 |
| Carbon monoxide.. | 3.69 | nil | 2.45 | 2.58 |
| Methane ..... | 0.51 | 0.31 | 0.95 | 0.39 |
| Acetylene ..... | 0.04 | nil | 0.27 | nil |
| Hydrogen ..... | 3.55 | 0.47 | 2.08 | nil |
| Total .....| 100.00 | 100.00 | 100.00 | 100.00 |

It is quite clear that the extreme tip of the outer flame of the Bunsen is the only portion that ought to be used for the heating, and if gas cooker makers would only bear this in mind and regulate the distance between the burners and the utensil to be heated, they would not only get a large amount of heat but would enormously increase the hygienic properties of their stoves.

# PRE-ROMAN DISCOVERIES IN SPAIN.

## BY THE PARIS CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

EXCAVATIONS carried on at Elché and Cerro de los Santos, in Spain, under the direction of M. Pierre Paris, a prominent archæologist, have yielded some very interesting finds relating to an epoch before the country was occupied by the Romans. These objects have been added to the Paris Louvre collections, and throw considerable light upon a period which may be compared to the Etruscan period of Italy. Here we find that Greek and Oriental influences are combined with the native element, and the result gives us a series of distinct and characteristic works of art.

AN ARCHAIC SPANISH HEAD. THIS SCULPTURE, WHILE SHOWING GREEK INFLURNCE, HAS ITS OWN INDIVIDUALITY.

SPANISH SCULPTURE OF THE GRECO-PHŒNICIAN PERIOD. NOW IN THE LOUVRE, PARIS.

AN EARLY SPANISH BUST, SHOWING TRACES OF ORIENTAL AND GREEK INFLUENCES.

PRE-ROMAN DISCOVERIES IN SPAIN.

Among these objects is the bust shown in one of the illustrations, which possesses a considerable interest from several standpoints. It is sculptured in the stone of the region. Owing to the beauty of the type of person and the strange head dress and ornaments, it is superior to that which has formerly been found in these regions. The ornaments are executed with care, and the *ensemble* shows that this art, even though it belongs to a comparatively primitive period, was already well developed. Excavations are not carried out as yet in a regular way at Elché, and in fact the workmen found the present piece while carrying on some work in the fields in the neighborhood of the Alcudia, which is the name given to the ruins of the Roman colony of Ilici. Up to the present time the only vestiges of this colony were in the shape of finds belonging to the Roman period, while the present specimens are much anterior to this epoch. Fortunately, the bust, although of comparatively fragile material, is in a very good state of preservation, and what is remarkable is that there are traces of color upon the face. This is seen especially upon the lips, and also on the head dress and drapery, which were colored in red, at least partially. The eyeball is hollowed, as was often the custom, in order to receive an incrustation which imitated the natural eye and gave a lifelike appearance to many of the ancient statues, but the material has fallen out. M. Pierre Paris considers that the bust represents a native type with local costume, and is an example of ancient Spanish art, much influenced by Oriental methods and coming more superficially under Greek influence. What may be the relative proportion of these influences is doubtful to decide, but at any rate we may observe all of them here. The head shows a grace combined with severity and is treated somewhat in the archaic style. What is striking are the two very large circular ornaments which are placed on either side of the head, and have a design in relief resembling the spokes of a wheel. The triple necklace is of a rich design, and is charged with ornaments resembling amulets, these being in the form of a type of small vase known as *amphorula*. Upon the head is a kind of miter of low form which has a complex ornamental design. We recognize here the somewhat curious character of the female ornaments which are mentioned by Strabo as belonging to the Iberian region, and are characterized by him as striking and picturesque, although somewhat exaggerated, perhaps, and certainly not in accordance with the more simple Greek or Roman costume. The difference lies in the fact that in these regions, although Greek in part, the Oriental influence still prevailed to a considerable extent, although the precision and delicacy of the work show the hand of a Greek artist, or at least one who has come under Greek influence. What is interesting in the present finds is that they show the existence of a native Iberic art which is to be placed parallel to Etruscan and to Cypriote art, these coming from a combination of Phœnician and Greek influence, with some of the native elements added. But neither in the Etruscan or Cypriote art do we find that the association of Greek perfection with barbarous or native influence has produced as fine a specimen as the present bust, which gives a reminiscence of the archaic virgins of the Acropolis of Athens.

A number of other specimens have been found at Elché and Cerro de los Santos, some of which we illustrate here. One of these is a curious female head with a tiara of considerable height, the lower part of which is brought down so as to cover the ears. The front part is ornamented in a relief design. There is also a female statue which has been recently found which gives a good idea of the costume of this period. It will be noticed that the head dress has a certain resemblance with the former one, but also differs from it in many respects, notably by the absence of the ornamented disks and the manner of arranging the braids of hair, which hang down at the sides.

M. Henzey, one of the most eminent archæologists and connected with the Louvre administration, considers that excavations in this region are likely to be of great value, and will, no doubt, discover a rich mine of specimens. These will throw light upon the semi-civilized Greek-Phœnician period which preceded the colonization of the country by the Romans. It may be noted in the bust which is shown here that it is not broken off, but is naturally finished at the breast. There is a circular opening in the back and a deep cavity which seems to have been used for receiving the ashes of the dead, or perhaps votive offerings. No doubt the present statue has a votive character, as was usual in these periods, and was perhaps a funerary bust.

# THE MANOMETRIC APPARATUS OF FISHES.

## NATURE'S MECHANICAL ADAPTATIONS.

BY DR. OTTO THILO.

THE swim bladders of some fishes are furnished with very singular appendages, essentially similar in construction to the manometers or gages which indicate the pressure of steam in boilers. These contrivances are found only in species in which the swim

FIG. 1.—DIAGRAM OF KITCHEN BOILER WITH STANDPIPE *S*.

bladder is filled with air at high pressure which is subject to great and sudden variations when the fish dives or rises to the surface, so that the distended bladder would be in danger of rupture if it were not provided with valves. The proper moment for opening

FIG. 2.—MANOMETER OF HERRING, PARTLY OPENED. (3 TIMES NATURAL SIZE.)

these valves is indicated to the animal by the natural manometers which establish a connection between the front of the swim bladder and the brain, and which, therefore, resemble steam gages in function as well as in form.

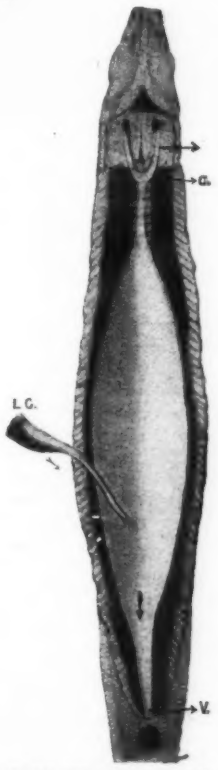
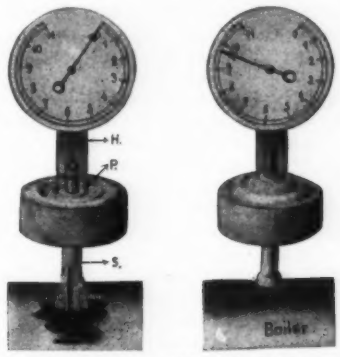



FIG. 2A.—SWIM BLADDER OF HERRING.

*L*. Manometer. *G*. Diaphragm. *L G*. Air inlet. *V*. Valve.

Steam gages are of two general types, of which one employs a standpipe filled with a liquid and the other makes use of the elasticity of thin metal plates. Both types are represented in the manometers of fishes.

I have found liquid gages attached to the swim bladders of herrings. A simple gage of this type, which is used in domestic water-heating apparatus, is illus-




FIGS. 3A AND 3B.—FLEXIBLE PLATE MANOMETER OR STEAM GAGE.

*H*. Lever. *P*. Plate. *S*. Steam pipe. In *A* the plate is horizontal and the pointer indicates a pressure of 0 atmospheres. In *B* the plate is convex and the pointer indicates a pressure of 10 atmospheres.

trated by Fig. 1. The steam pressure in the boiler is indicated by the height of the column of water in the tube above the water level in the communicating boiler. Gages of this type are used only for low pressures, of one-half atmosphere or less. Now, the swim bladder of the herring and its near relatives terminates, in front, in two narrow tubes arranged like the prongs of a fork (Figs. 2 and 2*a*). Each tube is about

FIG. 4.—ROTARY LINK.

A. Axis. B. Band.

1/12 inch in diameter just above the junction. Beyond this point it narrows, penetrates by a lateral orifice into the skull, and there expands. The tubes are lined with epithelium and are filled with liquid. Any change in the pressure in the swim bladder is thus communicated to the brain. The cavity of the swim bladder is separated from that of the forked tube by a thin flexible diaphragm at *G* (Fig. 2*a*). The existence of this diaphragm is proved by the fact that if the forked end of the bladder is cut off immediately above *G*, the bladder can be inflated and will remain

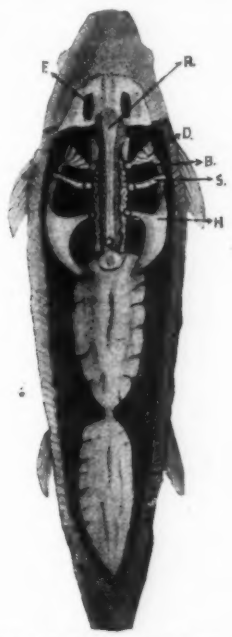



FIG. 5.—MANOMETER OF CARP, SHOWING SWIM BLADDERS COLLAPSED AND LIDS OPENED.

*F*. Aperture in back of skull. *R*. Spinal cord. *D*. Lid. *S*. Link. *H*. Lever. *B*. Band. (Manometer natural size, bladders and outline of body greatly reduced.)

inflated for weeks. I have also succeeded in detecting the diaphragm by the examination of sections under the microscope. Now, when the swim bladder is fully inflated the pressure of the inclosed air acts directly upon the diaphragm, which is forced outward, and thus the pressure is transmitted to the liquid which fills the forked tube.

When we study the habits of the herring we find that a pressure gage attached to its swim bladder is a very necessary organ. The walls of the bladder are quite thin and are frequently subjected to very great changes in pressure, for the quantity of air imprisoned in the bladder varies exceedingly. In freshly caught herring the swim bladder is always found nearly empty, and it can be inflated to an astonishing extent

FIG. 6.—MANOMETER OF CARP, SHOWING SWIM BLADDERS DISTENDED AND LIDS CLOSED.

by forcing in air through the air passage *L G* (Fig. 2*a*). The rapid evacuation of the distended bladder can be brought about by the fish in the following manner:

The bladder is connected with the anus by a passage furnished with a clack valve, *V*, which can be opened instantly when the gage indicates an excess of pressure in the swim bladder. The herring dives to great depths, and as a difference of 34 feet in depth corresponds to a difference of one atmosphere in pressure the swim bladder would be in danger of rupture if it were not provided with some such safety appliance.

Our most reliable steam gages, barometers, and manometers are constructed upon the same principle—that is, they are tubes filled with liquid—and they serve as standards of comparison for the elastic plate

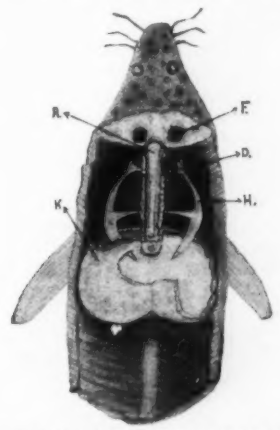



FIG. 7.—MANOMETER OF MUD FISH.

(3 times natural size.) *R*. Spinal cord. *K*. Bony envelope of swim bladder. *F*. Aperture in back of skull. *D*. Lid. *H*. Lever.

and dial manometers, like the steam gage shown in Fig. 3*A*. This consists of a metal box which communicates with the boiler through the pipe *S* and is closed above by a thin corrugated metal plate *P*. A lever *H* presses on the center of this plate and communicates its movement to the pointer on the dial. When the pressure in the boiler increases, the metal plate is forced upward (Fig. 3 *B*) and the pointer indicates the excess of pressure above that of the atmosphere.

The mud fish, the carp, and some other fishes possess manometers constructed on this principle. Fig. 7

shows the peculiar swim bladder of the mud fish, surrounded by a bony envelope, a part of which is removed to show the interior. To the membraneous swim bladder within are attached two jointed levers which turn on fulcrums in the vertebræ. The anterior end of each lever is connected by an elastic band with the hinged lid of a little hole in the spine. When the swim bladder is distended, the posterior ends of the levers are forced outward. (See also Figs. 5 and 6.)

Hence, the anterior ends of the levers are carried inward and the lids of the holes in the spine are closed, exerting pressure on the fluid of the spinal cord and brain, and thus indicating the pressure in the swim bladder. Conversely, the evacuation and contraction of the bladder turn the levers in the opposite direction, raise the lids, and relieve the pressure on the brain. That this pressure may be great is indicated by the existence of a sort of safety valve in the skull. In the back of the skull are two large apertures (*F*, Figs. 5 and 7) closed by a thin membrane which yields when great pressure is suddenly applied to the brain by the closure of the small openings in the spine.

In the carp (Figs. 5 and 6) a rotary guide link of bone (Fig. 4) is interposed between the lever and the lid. This guide is not found in fishes like the mud fish, shad, and electric eel, in which the swim bladder is firmly attached to the ribs and covered by a stout cartilaginous or bony envelope. The swim bladder of the carp is less rigidly attached, and consequently the levers are subject to displacements at right angles to their plane, which would impair the accuracy of the manometer. This source of error is removed by the interposition of the guide link, which has a remarkably long axis of rotation. Hence, its plane of rotation is little affected by lateral deviations of the lever, and these have no appreciable effect on the movements of the lid. The axes of the lid and the lever are nearly as long as the axis of the guide link.

In the mud fish (Fig. 7), on the contrary, the lever has no axis, but turns about a point pressed against the spine. The long axis and the guide link are not needed because the posterior end of the lever moves in a slit in the bony envelope of the swim bladder, and the whole lever is closely surrounded by masses of bone, so that it cannot deviate from its normal plane of rotation. Between these two extreme forms, represented by the carp and the mud fish, a great variety of intermediate forms is found. The pressure or absence of the guide and the peculiarities of the levers are dependent upon the construction of the swim bladder, which may consist only of a tough membrane or may be partly or entirely surrounded by bone. Swim bladders of all three of these types are found in the single family which includes the shad. The whole manometric apparatus is so small that a magnifying glass must be used in dissecting it and studying its movements, which are easily understood when they are compared with those of steam gages.

It is evident that this comparison did not occur to my predecessors in this field and that they did not thoroughly investigate the motions of the little bones. These bones were first described in 1820 by Emil Weber, who likened them to the small bones in the ear and gave them the same names—hammer, anvil, and stirrup. Hence, he assumed that the swim bladders of the carp and some other fishes served, in a measure, as organs of hearing. This view was not generally adopted. Gegenbaur, and also Bridge and Haddon, after minute study of the subject, asserted that the so-called Weber's bones had nothing to do with hearing, and that they were, for the time being, inexplicable. They have since been regarded as one of the unsolved riddles of science.

If the posterior swim bladder of a carp is squeezed by the hand, thus increasing the pressure in the anterior bladder, the movement of the levers and the closure of the little lids can be observed with the aid of a lens, and when the skull is opened the fluid contents of the brain can be seen to move in response to pressure applied to the swim bladder.—Umschau.

# UNUSUAL AGENTS OF POLLINATION.

## SOME CURIOUS DEVICES OF NATURE.

### BY G. CLARKE NUTTALL, B.SC.

THE cross-fertilization of flowers is commonly said to be brought about either by the wind, as in the pines and the hazels, or by insects, as in lilies, jessamine, and orchids. And among insects, the bees, the moths, and the various kinds of flies are those which gain all the credit, in the popular mind, of being beneficial flower visitors. Though this assumption is justified to a great extent, inasmuch as these two agents account for the large majority of cross-fertilizations effected in the flower world, yet there is an important minority of plants which depend on outside agents other than these to give that magic touch which alone can call posterity into being, and the consideration of these rarer agents of pollination is one which brings forward various points of interest in the interaction between the plant and animal worlds.

For instance, the fact that certain plants rely for the fertilization of their flowers upon bats has only been recognized within the last few years, and our knowledge upon this point is certainly not yet fully exploited. In the Royal Botanic Gardens at Trinidad the work of bats in this respect has, however, come under direct observation. A certain tree known as *Bauhinia megalandra*, which grows to the height of about thirty feet, produces in January each year long, white flowers which first appear in the later part of the afternoon and gleam out in their full glory in the dusk. About half-past five, when the dusk begins to deepen into darkness, the bats come out of their day hiding-places and fly swiftly hither and thither. The white gleaming Bauhinia tree specially attracts them, and they quickly pounce on the flowers one after another to the great injury of their beauty. For a bat, when it settles on a flower, secures itself by seizing on the white petals whose delicate fabric cannot withstand the rough onslaught, so fragment after fragment flutters to the ground as the bat struggles for foothold. The stamens, too, show traces of rough usage, and are sometimes torn right away and follow the petal fragments, but the stigmas in the center of the flower remain for the most part unharmed. One would naturally imagine that the bats found nectar in these flowers as their visits are so eager, but a close examination shows that the flowers contain in themselves no honey or anything else of that nature of value to the bats, but doubtless they harbor many small insects, and so the bats are attracted, for they find a generous meal in the depths of the flower with very little expenditure of energy.

A Wallaba tree (*Eperua falcata*) growing in the same gardens is also visited largely by what were first taken in the dusk to be big moths, but a more minute inspection showed that these "moths" were really little bats of a variety that has the same kind of brush-like tongue that a humming bird has, and whose name, *Glossonycteris geoffroyi gray*, does not accord with their size. These little bats flit about and act precisely after the manner of moths. In both the Wallaba and the Bauhinia it is evident, from subsequent events, that the bats are the direct agents that bring about the cross-fertilization of the flowers, and the transference of pollen is wholly effected during their visits.

Another plant that appears to be fertilized by bats is a Java creeper—by name Freycinia—which climbs to the very top of trees and produces pale rose-colored flowers, some male and some female, among long, dark green leaves. Now a certain well-known bat, the Kalaya, or Flying Fox, particularly affects this creeper, for it tears out the three inner petal structures and devours the succulent tissue with avidity. But this wanton destruction by the bat is amply made up to the flower by the fact that, as it eats the petals of the male flower, its head becomes covered with pollen from the stamens; and while it munches those of the female its head perforce rubs some of its golden burden on to the stigma and so cross-fertilization is insured, and, though the flower loses its petals, it gains posterity.

We know, at present, of no cases of pollination by bats in the flora of Europe.

Birds, too, must be classed among the rarer but undoubted agents of pollination. In Europe, perhaps, again, no authentic cases of regular pollination by birds are known, but in many other parts of the world—the Tropics, South Africa, Philippine Islands, New Zealand, Madagascar, etc., birds play a definite and prominent part in this work. Fritz Muller, whose researches into the pollination of plants are classical, says: "Humming birds, which constitute one of the most important groups of pollinators, are on the wing in Brazil throughout the year. Their activity in visiting flowers is far greater than would appear from accounts known to me. I could almost believe that the list of flowers not visited by them would be considerably smaller than a list of those that are visited" (i. e., of Brazilian flowers). One reason why they have not received all the credit due to them as pollinators is because some of their species are so remarkably like a certain hawk moth—known as the humming bird hawk moth—that frequently they have not been distinguished apart by naturalists. Bates, in "The Naturalist on the River Amazon," tells how he was completely deceived on various occasions, and once actually shot a humming bird hawk moth for the bird itself.

The tropical Abutilons are flowers that are almost entirely fertilized through the agency of humming birds. Fritz Muller, writing from Brazil, says: "A large and beautiful humming bird, the black breast of which shines like a glowing coal whenever the bird is in any way excited, has, with his inconspicuous wife, made himself almost completely master of the Abutilons in my garden, and drives away all other species. All flowers that are not under cover are pollinated by him."

The climber *Marcgravia* (a Nicaraguan plant) carries aloft pendulous flowers which hang in circles, a dozen or more together, from one stalk. Below the flowers sway numerous nectaries of pitcher form which hold large quantities of nectar. This attracts many insects, and they in their turn are sought by humming birds, who, in picking them out of the pitchers, rub their backs upon the drooping stamens and transfer the pollen from one flower to another.

In North America not only are many native flowers pollinated by humming birds, but also various species of European plants, which, in their own country, have their pollination performed by insects with long probosces; such plants, for instance, as the evening primrose, the red clover, and the figwort being visited and pollinated by these birds.

The banana is another plant that has this service frequently performed for it by birds. Indeed, its pollen is particularly adapted for this method of transmission, as the grains are bound together in numbers by threads, and in Natal, birds of the Cinnyridæ species may often be seen in the banana groves carrying it about on their beaks. On the other hand, the bananas of Mauritius do not appear to be frequented by birds at all, and there the transference of the pollen is made by insects.

Though small birds, such as humming birds and honey-suckers, form the large majority of bird pollinators, yet in some cases much larger birds fulfill this office. For instance, the large flowers of Carolinea are far too big for little birds to negotiate, so they look to woodpeckers to be their pollen carriers, and these birds, no doubt, search both for honey and for insects in the recesses of the flowers.

In one curious case succulent petals are the bait held out to birds, just as they are to bats in the Bauhinia. The flower of a certain Brazilian tree known as Feijoa—a myrtle—is deep red and particularly striking. As it matures, the red petals, which are then fleshy and sweet, roll up and disclose a shining white inner surface so that they form four little white rolls, which have been compared to omelettes. Anyway they are a *bonne bouche* to various birds who search them out and rapidly devour them, and during the meal successfully cover themselves with pollen. This pollen they carry away, and while feeding on the next similar flower rub some of it off on the waiting stigma, and meanwhile are again sprinkled with a fresh supply. But with birds, as with bats, there yet remains much to be added to our knowledge of them as pollinators.

One of the most curious and certainly one of the rarest pollinators as a class are slugs and snails, yet they, too, must be classed among the direct agents of pollination. The plants that come under their influence—malacophilous plants—have usually small flowers set closely together, such as we find in the family of the Compositæ, or in the Aroids where male and female flowers are massed within a sheathing spathe, and snails as they wend their slimy way across them drag the pollen grains along and distribute them. A certain Italian, Delphino, was the first to call attention, a number of years ago, to this possibility, for he observed that in various plants under his observation, such as *Rohdea japonica*, *Alocasia odora*, *Anthuriums*, and others, only those which were touched by snails set seed, the others did not. Unlike birds and bats, snails and slugs act as pollinators in this country. For instance, the ox-eyed daisy is frequently visited by a small snail in wet weather when flying insects are not in evidence. The snail feeds upon the white ray petals, and as it crawls around it very effectually performs the insect's work of pollination. The same thing has been observed in the golden saxifrage, and also in the common duckweed. Hence, even if we consider that snails are "only the occasional and not the exclusive agents of pollination," these facts prove, as Ludwig observes, "that plants which lack the customary agents of pollination when continuous rains occur during the flowering season, and would otherwise produce no fruit, may find in slugs effective substitutes for insects which are only active in dry weather."—Knowledge and Scientific News.

# THE STUDY OF FLAME.*

BY PROF. A. SMITHELLS, F.R.S.

ONE of the questions that first meet us in the study of flames is that of the temperature at which in any given case the phenomenon becomes evident. The old idea that there existed a fixed temperature at which inflammation suddenly took place cannot now be maintained, and the term "ignition temperature" has acquired a different meaning. It is now known that in a very great number of cases a mixture of two flame-forming gases, when gradually raised in temperature, will develop luminosity quite gradually with the chemical combination that is being induced. This phenomenon is, of course, known universally in connection with phosphorus, but it is not so widely known in connection with other combustible substances. Sulphur, arsenic, carbon disulphide, alcohol, ether, paraffin, and a whole host of other compounds, inorganic and organic, will phosphoresce as truly as phosphorus itself; in fact, phosphorescent combustion is the normal phenomenon antecedent to what we ordinarily call flame. This is, after all, only in harmony with the general truth that chemical combination between two gases does not set in suddenly, but comes into evidence quite gradually as the temperature is raised from a point at which the action, if it occurs at all, is so slow as to be negligible. The increase in the rate of combination is, of course, very rapid as compared with the increase of temperature, a difference of about 10 deg. C. (50 deg. F.) serving to double it. The interval between the beginning of phosphorescence and the production of vigorous flames may therefore be very short. In the case of phosphorus this interval, being from 7 deg. to 60 deg. C. (44 deg. to 140 deg. F.) includes ordinary atmospheric temperatures; hence the phosphorescence of phosphorus is a phenomenon that could not well be overlooked. If the prevailing terrestrial temperature were below 7 deg. C. (44 deg. F.), at which, under normal air-pressure, the phosphorescence of phosphorus ceases, it is possible that this element might never have acquired its peculiar reputation; it would not have shone in the dark, and in lighting it with a taper the phosphorescent interval would have been passed over as quickly as is ordinarily the case in the ignition of sulphur, paraffin, and other common combustibles. To make phosphorescence apparent in these last cases it is necessary to take special care to heat up a mixture of the combustible gas and air gently, and to maintain it at a temperature approaching, but not quite reaching, that of ignition. There is no simpler way than that used by Sir William Perkin, who brought the combustible substance near to, or in contact with, a massive metal ball previously heated to the suitable temperature. The change from phosphorescence to ordinary flame is not sudden, but the appearance of ordinary flame is the end point of a continuous, though rapid, development. This end point is the temperature of ignition. What, then, determines the temperature of ignition? The answer to this question has been given with characteristic conciseness by Van't Hoff, as "the temperature at which the initial loss of heat due to conduction, etc., is equal to the heat evolved in the same time by the chemical reaction." We may obtain a clear idea of the meaning of temperature of ignition by supposing a combustible mixture of gases such as that of air and the vapor of carbon disulphide to issue through an orifice into an indifferent atmosphere. If we surround the orifice by a ring of platinum wire, which is gradually heated up by a current of electricity, a flame will gradually make its appearance. If, as soon as this is observed, the heating of the wire by the current be discontinued, the flame will disappear; it is, in fact, not self-supporting, but depends on the accessory supply of heat through the electrically-heated wire. If, now, we raise the ring to a higher temperature, we shall get a brighter flame, owing to an increased rate of chemical action, and at last we shall reach a point where it is possible to cut off the electric current without causing at the same time the extinction of the flame. This is the true temperature of ignition, the temperature at which the reaction proceeds at a rate just sufficient to overbalance the loss of heat by radiation, conduction, and convection from the burning layer of gases, so that the next layer is put in the same state, and steady combustion proceeds. Phosphorescence has been spoken of as degraded combustion, and, though literally the appellation is correct, it is liable to be misunderstood. Again, it is often supposed that phosphorescence is necessarily associated with the formation of incompletely oxidized products. This may be the case in a chemical system which is capable of affording different products at different temperatures, but it is not an essential feature; the phosphorescent combustion of sulphur, for example, affords nothing but sulphur dioxide. Temperature of ignition is, then, neither a temperature at which combination suddenly begins, nor one dependent solely on the nature of the combining gases. It will vary with the proportion in which the gases are mixed and with their pressure and other circumstances. Notwithstanding the simplicity of this conception, it must be admitted that there are many obscure facts connected with the ignition of gases. The inflammability of gaseous mixtures is not necessarily greatest when they are mixed in the proportions theoretically required for complete combination; the influence of foreign gases does not appear to follow any simple law; the presence of a very small quantity of a foreign gas may exercise a profound influence on the ignition temperature as in the case of the addition of ethylene to hydrogen. When a mixture of methane and air is raised to its ignition temperature, a sensible interval (about ten seconds) elapses before inflammation occurs. These facts are cognate to others which have increased upon us so abundantly in connection with the influence of moisture on chemical change. The study of the oxidation of phosphorus in particular brings us among rocks and shoals. Apart from the influence of moisture on the combination, we have the limitation of the process by a certain tension of oxygen and by minute quantities of a vast number of chemical substances, among which, in spite of much labor, no other common bond can be found. We do not know what oxide is initially formed in the oxidation, and the existence of the oxides $P_4O$ and $P_2O$ is as confidently disputed as it is affirmed. There is some reason for believing that the phosphorescence connected with phosphorus succeeds the formation of one oxide and accompanies the formation of another. The state of the oxygen, whether atomic, ionic, or molecular, which acts on phosphorus, the induced oxidation of other substances, the ionization of air accompanying the oxidation—these are all matters concerning which there exists a bewildering literature that hangs over us like a cloud. The subject, simple as it appears at first sight, is really involved with a vast number of unsolved chemical problems, the elucidation of which would throw much light on chemical action in general. The structure of flames has always been regarded as dependent upon the chemical changes taking place in the differentiated regions, but until recent times little attention has been given to any question beyond the cause of the bright luminosity of hydrocarbon flames. In a flame such as that of hydrogen or carbon monoxide, where we have some reason to suppose that the same kind of chemical transaction is taking place throughout the region of combustion, we should not expect to find a differentiation of structure, and, as a matter of fact, we do not find any. Erroneous ideas have gained currency from the use of impure gases, and hydrogen is still described as burning with a pale blue flame, although Stas long ago stated that if the gas is highly purified, and the air freed from dust, the flame even in a dark-room can only be discovered by feeling for it—a fact consistent with the line spectrum of water lying wholly in the ultra-violet. The presence of a very small quantity of free oxygen in carbon monoxide destroys the perfect simplicity of the single shell of blue flame with which the purified gas burns, and in other flames small quantities of gaseous impurities or of atmospheric dust give rise to features of structure and halos which have been frequently supposed to pertain to the flame of the combining gases. The fringe of a flame in air may be often tinged by the presence of oxides of nitrogen. No flame better illustrates the relation of structure to chemical processes than that of cyanogen, where the two steps in the oxidation of the carbon are clearly marked out in color. Apart from hydrocarbon flames, very few others have been carefully explored from this point of view. The use of single hydrocarbons instead of the mixtures present in coal-gas and other common combustibles has simplified the study considerably. Two problems stand out prominently: one is to trace the steps in the oxidation of the hydrocarbon, the other to account for the bright patch of yellow luminosity. With regard to the question of the luminosity, I do not think there is any longer doubt about its being due essentially to the separation within the flame of minute solid particles of what is practically carbon. The separation seems to be adequately explained by the high temperature of the blue burning walls of the flame, which decomposes the unburned hydrocarbon within. In a similar way, arsenic and sulphur and phosphorus are liberated within flames of their hydrides; but these elements, being volatile, do not appear as solids unless a cold object be placed within the flame. In the case of the hydride of silicon the liberated element at once oxidizes to form the solid non-volatile oxide, which gives a bright glow. The mode in which a hydrocarbon yields carbon by the application of a high temperature has been the subject of experiment and of hypothesis; but neither the view of Berthelot, that the carbon results from a continuous coalescence of hydrocarbon molecules with elimination of hydrogen, nor that of Lewes, according to which the formation and sudden decomposition of acetylene is the essence of the phenomenon, appears to be in harmony with the experimental facts. It is certainly not easy to ascertain experimentally the changes undergone by a single hydrocarbon as its temperature is raised, and at the last it may be objected that the course of events in contact with the solid walls of a containing vessel is not necessarily the same as that within the gaseous envelope of a flame. I am glad to think that there is promise of further light on this subject from the work of Prof. Bone. Our knowledge concerning the question of flame temperatures has been much improved in recent times, thanks mainly to the admirable work of M. Le Chatelier. The well-known memoir of Mallard and Le Chatelier on the explosion of gases supplied the data which first permitted of a moderately exact calculation of flame temperatures, and the perfection of the thermo-couple by M. Le Chatelier gave us the first instrument that could be used directly for making a satisfactory measurement. The uncertainty connected with this subject may be well illustrated by quoting the temperatures that have at different times been ascribed to the flame of coal-gas when burnt in a Bunsen burner, where we have had values varying from 1,230 deg. to 2,250 deg. C. (2,246 deg. to 4,082 deg. F.) With regard to the use of thermo-couples, the practical difficulties have been successfully met. The chief difficulty is, of course, to secure that the thermo-junction attains as nearly as possible the temperature of the region in which it is immersed. As ordinary flames consist of thin shells of burning gases, on either side of which there is a very rapid fall of temperature, it is necessary to use thin wires, and to dispose them so that there is no appreciable drain of heat from the junction. By using wires of different gage for the couples it is possible by extrapolation to arrive at a temperature for a couple of infinitely small cross-section, and it is also possible to make a correction for the superior radiating power of the couple as compared with the flame-gases. With this last correction a maximum temperature of 1,871 deg. C. (3,400 deg. F.) was obtained as the highest temperature of the flame of a Bunsen burner burning coal-gas. The consideration of flame-temperatures has become of increasing importance in the arts owing to the use of the Welsbach mantle as a means of deriving light from coal-gas. The great improvements which have been made in the efficiency of atmospheric burners depend primarily on the fact that the smaller the external surface we can give to a flame consuming gas at a fixed rate the higher must be the average temperature; and since the emission of light from a mantle is proportional to a high power of the absolute temperature, a small increase of temperature is of great effect on luminosity. The acetylene-oxygen flame in which a temperature of about 3,500 deg. C. (6,332 deg. F.) prevails, not very different from that of the electric arc, is the hottest of the hydrocarbon flames, and finds some important practical uses.

There remains the general question of the luminosity of flames containing nothing but gases. The older explanation of the emission of light from combining gases said no more than that the energy liberated during the reaction and appearing as heat raised the product to incandescence—that is to say, so increased the velocity of its molecules and the violence of their collisions that vibrations were set up whose wave-lengths lay within the limits of visible radiation. This explanation has long been questioned, and there is now, I think, a very general agreement that it will not suffice. The average temperature, in fact, prevailing in a flame, if attained in the product of combustion by the supply of heat from outside, does not suffice to make that substance luminous. We are, therefore, thrown back upon the conclusion that the generation of light in a flame is not a consequence, though it is an accompaniment of the elevation of temperature. The question now is, Can we go any further? To do this we are led to consider individual molecular transactions instead of statistical averages, and the view presents itself that the combining atoms may, in losing their chemical energy, form directly systems of independent vibration where the radiation is such as to fall within the limits of visibility. If we picture such vibrating systems momentarily formed, it is easy to see that by their collision one with another they may acquire in a secondary way increased translational motion, and so lead to a state of things where the greater part of their energy is degraded in the form of heat. The high temperature of a flame would then be a consequence rather than a cause of its light. This subject of the mechanism of luminosity, however, like so many others, has now become involved with the theory of electrons. Some years ago attention was called to the scantiness of our

* Abstract of an address before the Chemical Section of the British Association for the Advancement of Science.

knowledge of the chemical changes that take place when metallic salts are used in flames for the production of spectra. Though there was general agreement that, for example, the yellow flame produced by common salt was due to the liberation and glow of metallic sodium, there was no agreement as to how the sodium was set free. Arrhenius, pursuing the analogy which exists between the laws governing matter in the gaseous state and in the state of dilute solution, had previously been led to the view that the electrical conductivity of flames containing salt vapors was due to ionization of the salt throughout the volume of flame. It appeared possible, therefore, that the luminosity might be ascribed likewise to the metal separated in the ionic state. Experimental investigation undertaken with a view to elicit information on this subject seemed to favor the view that the metal was reduced by chemical processes, and that it glowed in the un-ionized condition. Evidence seemed to point to the conclusion that, for example, when common salt is introduced into the flame of coal-gas the sodium chloride yields sodium by the conjoint action of steam and reducing gases; when liberation of the metal was prevented by adding a large quantity of hydrochloric acid to the flame the glow disappeared, but the conductivity was not always diminished. The fact that sodium salts, including the chloride, impart their characteristic glow to the flame of cyanogen and to other flames in which water is absent leads to some difficulty in finding a chemical explanation, and it must be admitted that a direct thermal dissociation of an alkaline halide or oxide is not out of the question. The interval of detachment of the metallic atom may be exceedingly brief, but it must be remembered that even so short a time as the interval between the molecular encounters in a gas at a high temperature is still sufficient for the emission of thousands of undisturbed characteristic vibrations. Very interesting and important investigations have been carried out by Lenard, who has shown that the stream of luminous vapor produced from a sodium salt in a Bunsen flame is deflected in an electric field in such a way as to indicate that the vapor is positively charged; but he gives reason for believing that the charged condition is intermittent with the neutral condition. The lines in the spectrum of an alkali metal are divisible, as is well known, into distinct groups or series, in each of which the oscillation frequencies corresponding with the lines are in a definite mathematical relationship. The principal series, which include the lines seen individually as such in ordinary flame spectra, are according to Lenard, due to the electrically neutral atoms. In a salted spirit flame, and in other flames of low temperature where only lines of the principal series are represented, the stream of luminous gas does not behave in an electric field as if it were charged. In the flame of coal-gas burned in a Bunsen burner, the salt-vapor gives, in addition to the distinct lines of the principal series, diffuse bands of luminosity on the dark background, which, according to Lenard, represent the undeveloped subordinate series; and it is the atoms emitting these series that are deflected in the electric field. It is inferred, therefore, that the light in a salted Bunsen flame comes from different groups of centers of emission—the principal series from the neutral atom, and the lines of the first, second, and third subordinate series from atoms which have lost respectively one, two, and three electrons. Lenard goes further, and shows that the salt-vapor in a Bunsen flame, as in the flame of the electric arc, emits these different kinds of radiation from different structural regions; thus the vapor at the edge of the flame is electrically neutral and gives only the lines of a principal series. The negative electricity in a salted flame would, according to Lenard, be disembodied, and recent experiments by Gold confirm the view that the negative carrier in flames is a free electron. The subject is obviously one of fundamental importance in relation to spectrum analysis, and my own slight connection with it has only strengthened my opinion that there is still a great deal connected with the genesis of spectra that requires the attention of the chemist even more than that of the physicist.

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**An invention** lately patented by the Deutsche Gasglühlicht Aktiengesellschaft relates to tungsten filament glow lamps, and consists in employing carbon suspenders in place of the suspenders of metal or the refractory metallic oxides which have hitherto been generally used for this purpose. As carbon possesses the property of good radiation for heat rays, this support remains comparatively cool, even near the point of contact, and can, therefore, be made very thin. Carbon suspenders have been found to be unsatisfactory for osmium lamps, owing to the formation of osmium carbon compounds; but this objection is not present when tungsten is used. The suspender is attached to the filament by means of a suitable cement, the carbon being made of such thinness that it will allow sufficient movement in the lamp filament when switching on and off, and rupture of the filaments is thus prevented.—The Engineer.

## SCIENCE NOTES.

**Uruguay** is said to be rich in minerals. So far this source of wealth has been almost entirely neglected. With the exception of granite quarries in various parts of the country and four gold mines at Cuñapirú, in the department of Rivera, the mineral deposits have not been worked. In the past year, however, according to a recent consular report, great interest has been manifested by mining men in the possibilities of various goldfields. Several mining engineers and prospectors from South Africa and elsewhere have reported on the prospects.

**Astronomical science** loses one of its most eminent workers in the death of the eminent director of the Paris Observatory, M. Maurice Loewy, which occurred suddenly on the 15th of October at the age of 75. For a long time past M. Loewy has been identified with the work of the observatory, having been associated with the celebrated astronomer Leverrier at the outset of his career, and in later times he was especially engaged in observations upon the planets, the moon, about whose formation he advanced some new theories, meteorites, and the determination of longitude. Born at Vienna in 1833, he was naturalized in France in 1864, and was made a member of the Académie des Sciences in 1873. Having the post of sub-director of the observatory in 1878, he assumed the position of director ten years later. To him is due the construction of the great equatorial, for which he designed the plans. Within the last few years he was occupied with lunar photography and the preparation of the photographic atlas of the moon.

**Some thirty years ago** Lord Rayleigh made an extensive series of experiments in order to ascertain more precisely what are the capabilities of the ears in estimating the directions of sounds. It appeared that even with pure tones, the discrimination between right and left sounds could be made with certainty, and without moving the head. But with pure tones no pronouncement could be made if the sounds were situated in front or behind the observer. With the speaking voice, front and back could often be distinguished. The discrimination between right and left is usually supposed to be explicable by the greater intensity of sensation experienced by the ear which lies nearer to the sound. Lord Rayleigh considers that this explanation is adequate when the pitch is pretty high. But for a frequency of 256, the difference in intensities at the two ears is far from conspicuous, and at 128 it is barely perceptible. Theory indicates that the difference of intensity in the case of a pitch of 128 should be decidedly less than one per cent of the whole; yet the discrimination between right and left is as easy as before. Lord Rayleigh has recently returned to the question, commencing with a frequency of 128. Every precaution was taken to remove bias. The observer, either on his feet or more conveniently seated upon a rotating stool, is turned round until he loses his bearings. It is often necessary to cover the eyes with the hands as well as to close the eyelids, in order sufficiently to exclude the light. With different observers it was a moot point whether there was any balance in intensity for the source on the same side as the open ear in the case of frequency 128, while with 256 the difference was marked. Thus there are cases where it is impossible to attribute the correct judgment of direction to the relative intensity. The only other circumstance in the case of pure tones is the relative phase of the notes at the two ears. The sound reaches one ear later than the other, and the same statement holds good for all the successive condensations in the wave train. If this phase difference is admitted as a source of the power of discrimination, it must be limited to sounds of low pitch. The retardation for frequency 512 would be about half a period, for 1,024 a whole period, and so on; and since any number of whole periods are equivalent to no retardation at all, such a retardation can be of no avail as an explanation. In testing the applicability of the explanation to low pitches, two forks, electrically maintained, were placed in separate rooms, and the sounds led through composition tubing to the observer's ears. The forks were slightly out of tune, *so there was a progressive increase of phase difference* between the notes. The time for the retardation to change through a whole period was about five seconds. On the very first trial, Lady Rayleigh and Lord Rayleigh at once experienced a distinct right and left effect, *the sound appearing to transfer itself alternately from the one side to the other.* The beat may be slowed down until it occupies forty or even seventy seconds, with the same results. Further experiments showed that the transitions between right and left effects correspond to agreement and opposition of phase. When the vibration on the right is the quicker, the sensation of right follows agreement of phase and that of left follows opposition; and right and left may be interchanged in the above statement. These results, it may be repeated, apply only to pitches of 128 or under. At a pitch of 256 the effect is still present, but begins to be complicated by the differential intensity effect.

## ENGINEERING NOTES.

**The position of Russia** as the leading producer of manganese ores is now seriously threatened by the extensive development of deposits of manganese ore in India.

**A mixture of lead wool** and graphite is now being successfully used for packing valves. It is used in the same manner as asbestos or other similar packing is employed. This mixture may be used for high temperatures, and has some advantages over asbestos.

**For some time past,** says the Naval and Military Record, rumors have been current at Portland and Weymouth that the British Admiralty intended discontinuing the torpedo range in the Roads. The range has been found inadequate to meet the demands of the improved torpedo, the range of which has been greatly increased by the recent hot-air invention, and the authorities have decided to take the range elsewhere—probably to Loch Long, in Scotland. The decision of the Admiralty has caused a good deal of regret at Weymouth, as it is felt that another blow has been struck at the local torpedo industry, which is suffering from acute depression just now.

**The Germans** are carrying out a plan in the interior of Africa to divert to the German ports on the east coast the trade flowing over the Uganda Railway, a line subsidized by Great Britain. They have already built a railway from Pangani, on the coast, to the base of Mount Kilimanjaro, on the border of British East Africa. Swamps on the one side and mountain ranges on the other prevent this line from being continued to Lake Victoria Nyanza, but to overcome this difficulty a canal through the swamps from a deep inlet of the lake to the railroad is being dug. The canal will be sixty miles long and the overflow from it will be carried to the sea by the River Ruvu. Ordinarily such a work might not be considered a menace, but experts believe that, in the case of Lake Victoria Nyanza, it will do great damage to British interests. The lake has been falling for years, some of the rocks which now stand sixty-five feet above its level having not so many years ago been submerged. If further drained by this canal it is said that it will not be long before the steamers which now ply on the lake will no longer be able to navigate its waters. Some even say that any interference with the waters of the lake will affect the Nile supply, the lake acting as a natural reservoir to be drawn upon in the years when the Abyssinian rains fail.

**We recently drew attention** to the interesting development that is to be carried out by the International Marine in the construction of a liner equipped with a combination of reciprocating and turbine engines, the latter section of the equipment to operate the steam after it has been exhausted from the cylinders before passing to the condensers, with the object of securing the last ounce of power. Following this action, the Hamburg-American Line have placed an order with the Belfast shipbuilding firm of Harland & Wolff for a transatlantic liner to be engined upon the same principle. This vessel will exceed the "Lusitania" in length, being 840 feet long over all by 86 feet beam. In speed she will be of the intermediate class, similar to the "Oceanic" and sister vessels, the maximum speed desired being about 15 knots. The propelling equipment is to be carried out by Messrs. John Brown & Co., of Clydebank, the builders of the "Lusitania," with whom Harland & Wolff are now allied. The reciprocating engines will be of the quadruple-expansion type exhausting the steam into low-pressure Parsons turbines; and by means of a vacuum intensifier associated with the condenser, it is anticipated that there will be a considerably increased range of total expansion, the result of which will be an appreciable economy in the coal consumption. In fact, it is expected that this economy in fuel will approximate 12 per cent at 15 knots speed.

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